EPA-908/4-77-002

SUBIRRIGATED ALLUVIAL VALLEY FLOORS

A Reconnaissance of Their Properties and Occurrence on Coal Resource Lands in the Interior Western United States

DRAFT

U.S. Environmental Protection Agency
Region VIII, Office of Energy Activities
1860 Lincoln Street
Denver, Colorado 80295

March 1977

EPA-908/4-77-002

SUBIRRIGATED ALLUVIAL VALLEY FLOORS

A Reconnaissance of Their Properties and Occurrence on Coal Resource Lands in the Interior Western United States

DRAFT

U.S. Environmental Protection Agency
Region VIII, Office of Energy Activities
1860 Lincoln Street
Denver, Colorado 80295

March 1977

SUBIRRIGATED ALLUVIAL VALLEY FLOORS

- A Reconnaissance of Their Properties and Occurrence on Coal Resource Lands in The Interior Western United States*
March 1977

DRAFT

John E. Hardaway
Chief, Research & Applications Branch
Dan B. Kimball
Environmental Protection Technologist
Shirley F. Lindsay
Terrestrial Biologist
Jack Schmidt, Larry Erickson
Consulting Geologists

U. S. Environmental Protection Agency, Region VIII
Denver, Colorado

Introduction

Concern for Alluvial Valley Floors and the Impacts of Surface Coal Mining

Concern has been expressed regarding the long-term impacts of surface coal mining on lands in the western United States currently or potentially useful for agriculture. Part of this concern bears on disruption of these lands used by wildlife. In particular, there are questions regarding the potential impact of coal extraction in certain lowland areas of the semi-arid West where shallow ground water and/or soil moisture is adequate to support growth of grasses and forbs through the dry months. These land areas, located along drainage channels and referred to recently as "alluvial valley floors" (National Academy of Sciences, 1974), are most important in semi-arid and arid climates because water is "stored" in the alluvium, enabling vegetation to continue growth during the months of low rainfall. Apparently, soil moisture, and perhaps some near-surface ground water, subirrigates the vegetation.

The character of the vegetation is a function of both depth to water table (depth to saturated zone) and quality of the soil moisture and ground water. The depth to water table, as well as seasonal variations in this parameter, may be critical in determining the composition of the vegetation. For example, if the saturated zone is sufficiently near the ground surface to permit capillary migration of ground water to the surface, subsequent evaporation may cause accumulation of salts. Under such conditions, the vegetation may be comprised principally of salt-tolerant species, such as alkali sacaton (Sporobolus airoides). Similarly, the configuration and moisture retention characteristics of the capillary and remaining unsaturated zone may be the most critical elements of the ground water system that supports vegetative communities in the lowland areas. However, no one has yet reported on the essential functions critical to sustained growth of vegetation in these areas.

Alluvial valley floors are used for grazing and for production of hay. Both domesticated and wild animals are attracted by the more vigorous vegetative growth and the presence of surface water in these lowland areas. The alluvial valley floor areas include the principal surface water accumulation points, as well as points of ground water recharge and discharge.

The composition of vegetation in subirrigated alluvial valley floors is important since some grass and legume species are more desirable as hay. Some vegetative

* This article is based on a draft report being developed by the authors. However, no official support or endorsement by the Environmental Protection Agency or any other agency of the federal government is intended or should be inferred.

species develop root systems that extend perhaps ten meters deep to obtain sufficient water, but many grass species favored for hay are more shallow rooted (i.e., on the order of two meters in depth). Examples of these grasses include such native species as canada wildrye (Elymus canadensis), little bluestem (Andropogon scoparius), and blue grama (Bouteloua gracilis). The relatively shallow, fibrous nature of root systems characteristic of these grasses is documented by Heath et al. (1973) and Weaver (1968). The deeper-rooted species include forbs and woody plants which serve a useful role in supporting game animals as [illegible] cover and forage for domesticated animals such as cattle or sheep. Usually the vegetative growth of an alluvial valley includes native grasses. At times the alluvial valley floor may include alfalfa; however, alfalfa is generally considered to be a deep-rooted phreatophyte and may also be grown outside an alluvial valley. The alluvial valley can be important for agriculture in that it not only provides forage during the growing season, but also can provide sufficient vegetative growth for forage to be cut and stored for winter use. It is often possible to obtain three cuttings of hay in subirrigated alluvial valley floors.

DRAFT

The agricultural and wildlife uses of lands in the interior western United States* have been prominent since they provide the principal source of income. Though oil and gas production and now coal mining have provided some development and economic support to the region, they are activities which remove a non-renewable resource and which might be considered temporary compared to farming, ranching, fishing, hunting and enjoyment of scenery. It is important to insure that the agricultural and recreational economy is as strong, if not stronger, after mining as it was prior to mining. Thus, if the alluvial valley floor is critical to the success of a ranch or to the maintenance of local wildlife populations, these vital functions must be protected - at least until such time as it is demonstrated that the alluvial valley floor's usefulness may be efficiently and economically replaced by an alternative source of domestic fodder and/or wildlife habitat.

Surface mining of coal has the potential, in the western United States, to temporarily, and even permanently, change the ground water flow system. If the mine involves disturbances of saturated strata or aquifers, it is likely that while mining, the local water table(s) will drop somewhat and ground water flow will be intercepted by, or will be directed toward the mine pit. But this is a temporary situation, since in most cases the water table will be reestablished after mining is completed and the mine pits are backfilled and graded. However, if the mining disturbs confining strata that serve to isolate aquifers** which have significantly different potentiometric heads, such as that which appears to occur in the Sarpy Creek watershed in southeastern Montana, there may be a significant change in the depth to water after mining and reclamation.

Changes in the water table will also affect the postmining use of subirrigated alluvial valley floors. If changes in the depth to the water table are more than a few meters, it appears reasonable to expect some effects on vegetation in lowland areas. Phreatophytes (alfalfa, for example) are especially sensitive to changes in the depth to available water. Grasses with fibrous root systems are not able to penetrate deeply into the substrate. Such vegetation may be adversely affected if the post-mining water table is deeper or if the post-mining moisture holding capacity of the growth medium is significantly reduced. Effects on vegetation could involve a shift toward deeper-rooted and more drought-resistant vegetation, or a shift to shallow-rooted vegetation (the latter if the depth to water is decreased). Thus strata functioning as relatively impermeable lower boundaries for water tables in the alluvial valley floors might have to be recreated after mining to prevent undesirable lowering of the water table.

---

* The term "interior western United States" is loosely used to include North Dakota, South Dakota, Montana, Wyoming, Colorado, Utah, New Mexico, and Arizona.

** Aquifer: relatively permeable rock containing and conducting sufficient ground water to yield significant quantities of water to wells and springs.

Extensive mining of an alluvial valley floor, even when followed by reclamation, has the potential to produce impacts on uses of that water, both at the mine site and wherever the affected water flows. Overburden material (or spoil) returned to the mined area is in many cases more susceptible to oxidation and leaching of the elements than was the undisturbed overburden. Salts concentrations often increase after mining and are noteworthy since high salt concentrations in the soil solution impede the uptake of water by plant roots. High sodium concentrations (relative to calcium and magnesium) can also detrimentally affect soil structure and consequent uptake of water and oxygen by plants.

DRAFT

Table I contains representative results of ground water quality measurements collected by the Montana Bureau of Mines and Geology from two surface coal mining areas in southeastern Montana. Examination of this limited amount of water quality data first suggests that concentrations are highly variable and conclusions cannot be drawn. However, the analyses of ground waters near Decker, Montana, do suggest that spoiled overburden contains water with higher concentrations of most elements than water obtained from undisturbed overburden and coal (the strong exception is the carbonate ion). Spoils waters at the Decker mine are higher in specific conductance than waters collected from the shallow alluvium, undisturbed overburden, and coal. The increase is due, principally, to calcium, sodium, bicarbonate, and sulfate concentrations. However, indicative of data variability is the fact that the second-highest specific conductance at Decker mine was found in a sample collected from undisturbed overburden, and that concentration is higher than one of the spoil water samples collected at the same mine.

Water quality data from ground water samples collected near Colstrip, Montana, show trends similar to those collected near Decker (Table I). Spoils water is somewhat higher in specific conductance than waters from undisturbed overburden and coal. The ions contributing chiefly to this increase are calcium, magnesium, bicarbonate, and sulfate. Although sodium content was higher in Decker spoils water, it is lower in Colstrip soils water than in undisturbed overburden and coal. On the other hand, magnesium levels are higher in Colstrip spoils water, but about the same in spoils and undisturbed overburden at Decker.

It should be noted that the data in Table I are from samples which do not necessarily represent a long term, "before and after mining" analysis (i.e., no samples were collected in the same area before and after mining a particular location.) Thus comparison of the quality of water in undisturbed overburden and spoils does not necessarily indicate expected water quality following complete "reclamation". However, we do conclude that spoiled overburden contains ground water of poorer quality than in nearby undisturbed overburden and water-bearing coal seams, and thus that newly spoiled overburden has the potential, at least in selected circumstances, to produce ground water of relatively poorer quality. Whether deterioration in water quality will significantly affect overlying vegetation is not known. However, initial stands of vegetation on regraded lands at the Decker mine appear to be healthy one and two years following seeding. In the case of coal mining near Decker, Montana*, it has been projected that spoils water will have dissolved solids content ranging from 4,000 to 7,000 mg/l, principally sodium and sulfate, (USDI and State of Montana, 1976). It is also concluded that in spite of these high levels of dissolved solids in ground water, the cumulative impacts of the Decker operations adjacent to the Tongue River Reservoir on reservoir water quality, and thus on water uses, will be insignificant and difficult to detect.

Rahn (1976) has statistically analyzed twenty-eight ground and surface water samples collected from eight mines** in northeastern Wyoming and southeastern

---

* Current mining at the Decker and Rosebud mines at Colstrip does not involve direct disturbance of subirrigated alluvial valley floors.

**Wyodak Mine, Big Horn Mine, Decker Mine, Rosebud Mine (Colstrip), Big Sky Mine, Hidden Water Mine (abandoned), Antelope Mine, and Bell Ayr Mine. Appendix 1 provides a more complete listing of surface coal mines examined for alluvial valley floors in this report.

TABLE 1
SELECTED WATER QUALITY ANALYSES OF
GROUND WATER NEAR DECKER AND COLSTRIP MONTANA

	Specific Conductance Mmhos/cm	Concentrations in milligrams per liter (ppm) - Dissolved												
		Ca	Mg	Na	K	HCO_3	CO_3	SO_4	SiO_2	Cl	F	NO_3	Fe	pH(lab.)
Alluvium[1]	920	85	57	36	8	420	0	176	21	7	1.0	1.3	0.00	7.6
Alluvium[1]	2620	86	185	350	12	626	0	1152	27	11	0.3	0.3	0.01	7.9
Overburden (undisturbed)[1]	5060	31	13	1355	9	1996	19	1320	8.6	16	0.4	32.0	0.2	8.4
Coal[1]	1660	6	0.4	450	4	1139	23	8	9.0	16	2.6	0.0	0.9	8.5
Spoils water[1]	4390	67	66	995	16	1546	0	1248	13	30	0.6	1.0	6.5	7.2
Spoils water[1]	7281	202	63	1640	16	882	0	3464	20	21	0.3	2.0	0.23	6.8
Alluvium[2]	4240	402	924	500	8	334	0	5390	15	33	0.2	32.0	0.07	8.2
Alluvium[2]	2470	234	184	143	8	576	0	1110	25	13	0.2	1.2	0.1	7.5
Overburden (undisturbed)[2]	483	46	34	6	2	234	0	58	11	7	0.1	15	0.2	7.9
Overburden (undisturbed)[2]	3140	20	8	745	4	258	0	1400	6	13	0.5	0.2	0.08	8.2
Coal-Rosebud[2]	2490	141	288	93	6	923	0	919	12	7	0.0	1.1	0.01	7.6
Coal-McKay[2]	2540	217	199	160	8	594	0	1140	21	17	0.2	1.0	0.1	7.5
Spoils water[2]	4860	481	748	23	11	697	0	3640	17	3.2	0.2	0.3	0.3	7.3
Spoils water[2]	2990	333	317	58	12	629	0	1670	21	14	0.1	4.4	0.15	6.9
Spoils water[2]	2300	208	238	34	6	618	0	1060	18	7	0.0	1.5	0.18	7.6
Spoils water[2]	2920	317	269	60	9	724	0	1440	17	9.2	0.1	1.3	3.0	7.7

Note: These data were not collected from identical locations before and after mining and thus do not provide a comparison between disturbed and undisturbed spoils other than in a general sense.

1) Van Voast, W.A. and R.B. Hedges. 1975. Hydrogeologic aspects of existing and proposed strip coal mines near Decker, southeastern Montana. Montana Bureau of Mines and Geology, Bulletin 97.
2) Van Voast, W.A. and R.B. Hedges. 1975. Hydrogeologic conditions and projections related to mining near Colstrip, southeastern Montana. Montana Bureau of Mines and Geology. Preliminary Paper subject to revision.

Montana and concluded that:

> "Water in spoils was found to be significantly more highly mineralized than natural ground water in terms of total dissolved solids, calcium, magnesium, and sulfate. Spoils water exceeds the recommended drinking water limits in these and other ions (manganese and cadmium), and it is doubtful that the water could be used for long-term irrigation."

DRAFT

These higher concentrations will probably decrease with time as material is leached, and chemical forms change, but the rate of decrease is uncertain. McWhorter et al. (1977) have estimated, for northwestern Colorado, that if 20 cm of water infiltrates into the spoils annually it would take 680 years to reduce conductivities by 95 percent if weathering is not considered, and longer if weathering is considered.

Mining of an area upstream or "upgradient"* of an alluvial valley floor also affects the water resource and the character of the drainage system in terms of flow, carrying capacity of the channel, and channel stability (or resistance to erosion). Specific impacts are dependent upon the local and regional hydrology. Surface mining in, as well as outside, an alluvial valley floor can, for example, involve the diversion of streams. Often such diversions have been done without adequate regard for the slope of the channel (i.e., stream gradient). Though diversions could be generally considered as lengthening stream channels (since streams are being diverted away from their channels) and, therefore, as reductions in stream gradients, past diversions include the straightening of meandering streams such as the Belle Fourche River (Wyoming) resulting in a steeper gradient and diversions causing both lower and steeper gradients of streams such as Little Youngs Creek (Wyoming). If the gradient is significantly steepened, erosive capabilities of the drainage system are increased in the area of steepening. Concurrently, increased sedimentation will probably occur downstream. The post-mining grade of the stream is equally critical. Significant steepening of portions of a disturbed stream channel will result in progressive upstream channel and bank erosion and downstream deposition until, at some future time, equilibrium is again reached. Channel depths and widths will change as a result of the disturbance of equilibrium.

Surface mining of shallow coals in the western United States is now occurring in areas which have been identified as alluvial valley floors, in this report, and by others. These mines include the Belle Ayr, Eagle Butte, Cordero, Wyodak, PSO #1, and Big Horn mines in Wyoming (see Appendix 1 for locations). Mining at these sites has not been reported as adversely affecting alluvial valley floors other than where alluvial valley floors are actually removed during mining or where spoil is placed on the surface of the valley floor. Nor have pre-mining investigations of hydrology, vegetation, or operational hydrolic monitoring been comprehensively analyzed to predict the presence or absence of longer-term impacts of mining on these alluvial valley floors.

There is no strong evidence of chronic water pollution caused by the current coal mining operations in the interior western United States. There is limited evidence of surface water quality degradation in some streams such as Little Youngs Creek in northern Wyoming (due to intrusion of spoiled overburden into the alluvial valley floor). Water quality data collected along Little Youngs Creek are presented in Table 2. Samples collected in 1976 indicate a significant increase in total sulfates and dissolved solids across the disturbed area. The data also show a seasonal increase in total dissolved solids unrelated to the mine (upstream).

Measurements of impacts on water by surface mining in the western United States are limited. One must utilize sophisticated water sampling and analysis devices suited to allow sampling during infrequent runoff events, from remote locations, and

---

* "Upgradient" and "downgradient" refer to locations higher or lower along the potentiometric surface of the water table relative to the point of reference.

TABLE -

RECONNAISSANCE WATER QUALITY INFORMATION COLLECTED ALONG LITTLE YOUNGS CREEK AND YOUNGS CREEK, NORTHERN WYOMING VICINITY OF NEW SURFACE COAL MINE

WATER QUALITY DETERMINATIONS

Location	Date	Conductivity mhos/cm	Total Dissolved Solids (mg/l)	Total Suspended Solids (mg/l)	Sodium (mg/l)	Calcium (mg/l)	Sulfate (mg/l)	Cadmium[1] (ug/l)	Chromium[1] (ug/l)	Copper[1] (ug/l)	Lead[1] (ug/l)	Mercury[1] (ug/l)	Nickel[1] (ug/)	Zinc[1] (ug/l
1. Little Youngs Creek at Montana-Wyoming State Line. R39E, T 10S, NW, NE 22. Upstream of mine operation.	May 76	527	308	114	14	53	110	---	---	---	---	---	---	---
	Jul 76	788	502	69	20	70	80	6	25	25	40	<0.2	<25	45
	Nov 76	1010	690	38	30	37	238	5	5	<10	5	<0.2	25	15
2. Little Youngs Creek R84W,T58N, NE 22. Immediately upstream of overburden storage and haul road area.	May 76	526	316	190	14	52	120	---	---	---	---	---	---	---
	Jul 76	981	652	96	37	72	170	<5	30	20	50	<0.2	<25	20
3. Little Youngs Creek East Side of County Road. R84W,T58N, W, SW, NW 23. Downstream of mine operation.	May 76	541	328	754	14	53	200	---	---	---	---	---	---	---
	Jul 76	977	662	168	37	70	180	5	40	20	60	<0.2	<25	60
	Nov 76	1500	1010	53	145	40	450	5	5	<10	5	<0.2	25	20
4. Youngs Creek at Sheridan - Decker Road, State Highway 338, R83W, T58N, SW, NW 30.	May 76	996	670	114	40	74	260	---	---	---	---	---	---	---
	Jul 76	1298	952	11	60	62	380	<5	25	20	[illegible]	<0.2	30	20
	Nov 76	1790	1400	46	95	47	738	10	5	<10	[illegible]	<0.2	100	5
5. Discharge Pond at Mine Site - no discharge at time. R84W, T58N, NW, NE 22.	Nov 76	1500	1020	36	140	40	425	5	10	<10	[illegible]	0.2	<25	5

1) Concentrations are total (Dissolved + Suspended). Others, unless noted, are dissolved.

DRAFT

from ground water aquifers. Nonetheless, such monitoring is required. Only with the results of measurements at existing mines can projections be made for future mines.

Considering then the probable importance of subirrigated alluvial valley floors, and the potential for disrupting the hydrologic and biologic functions thereof, it was considered appropriate to evaluate the amount of land that would be classified as subirrigated alluvial valley floors. This paper reports efforts directed at the identification of alluvial valley floors as those areas are defined in proposed national legislation. Appendix 2 provides quotations from legislative proposals and Committee Conference Reports that have addressed mining in alluvial valley floors. These proposals may be summarized as indicating that an alluvial valley floor is:

- A geologic unit comprised of several parts: an active (as opposed to abandoned or buried) stream channel (perennial, intermittent, or ephemeral), a flood plain, and an adjacent low terrace, including alluvium with sufficient soil depth and suitable texture to support perennial grasses suitable for grazing or other agricultural use, and with sufficient channel stability to allow agricultural use;

- A hydrologic unit in which the natural surface water and ground water is adequate to support agricultural activities such as hay production, by virtue of sufficient moisture held available to enable continued growth of suitable vegetation during the dryer summer and fall months;

- A topographically-defined area in which the floor plain and adjacent low terraces may be irrigated by simple spreading of ephemeral waters and/or by simple diversion of natural flow*, and

- An area of land used for farming.

This report includes both a reconnaissance identification of subirrigated alluvial valley floors, through analysis of surface features, and a preliminary analysis of hypothetical subsurface conditions that appear representative of actual conditions. It was not possible to investigate the actual uses or productivity of those areas mapped as alluvial valley floors. In the context of proposed legislation, it is therefore inappropriate to directly transfer the areas of alluvial valley floors presented herein to an impact on surface-mineable coal since the proposed legislation applies to farmed areas (and to water quantity and quality) and "farmed areas" are not identified. It is similarly inappropriate to conclude that this study has adequately documented the hydrologic and biological systems that exist in alluvial valley floors. We have, however, attempted to provide an analysis of specific impacts on the hydrologic system that may result from surface methods of mining shallow coals. This study draws upon research performed by others to initiate an analysis of whether those functions of alluvial valley floors deemed critical in the study can be reestablished during mining and reclamation.

Research to Date

The concept of alluvial valley floors utilized recently is new to those not directly associated with western agriculture. Little research has been initiated on the geohydrologic and biologic inter-relationships within alluvial valley floors or on land use activities conducted therein. This section discusses pertinent investigations reported to date.

---

* We assume that the practice of spreading flood waters includes simple furrows and temporary stream diversions, but excludes extensive grading of land and/or construction of canals. These latter efforts may be used to convey water from streams and impoundments to high terraces covered with thin alluvium and colluvium and lying outside the subirrigated alluvial valleys.

The United States Geological Survey of the U. S. Department of the Interior conducted a field reconnaissance mapping of alluvial valley floors in the three-county portion of the Powder River Basin of southeastern Montana in 1975 (Malde and Boyles, 1976). In that study alluvial valley floors were defined as those low terrace and flood plain areas of drainages whose vegetation, in terms of species and cover, reflected the near surface availability of water. Terraces generally not higher than 1.5 meters above the channel floor of small streams and not higher than 2.5 meters above the channel floor of principal streams were included in the alluvial valley floor description. Areas obtaining all or the vast major[illegible] of water for vegetation from ditch irrigation were not knowingly included.

DRAFT

Malde and Boyles had no direct ground water data ju[illegible] their criteria and had to depend on knowledge of geologic and biologic phenomena. The areas mapped as alluvial valley floors supported vegetation systems dominated by grasses and often mixed with silver sagebrush (Artemisia cana) along small streams and in the upper reaches of large streams. Greasewood (Sarcobatus) and big sagebrush (Artemisia tridentata) were absent or rare in the alluvial valley floors mapped by Malde and Boyles. Greasewood and big sagebrush were usually considered indicators of deeper ground water and thus to be located outside the alluvial valley floor.

Malde and Boyles found that: (1) larger alluvial valley floors were found along the larger streams of the study area; (2) alluvial valley floor width generally increases in the downstream direction; (3) alluvial valley floors are generally continuous upstream from the mainstem of major rivers to the point where vegetative and terrace characteristics are lost; and (4) comparing the areas mapped with coal resource data, less than three percent of the area of strippable coal in the southeastern Montana study area is overlain by alluvial valley floors. Thus the size of alluvial valley floors was found, in practice, to be a direct function of annual flows, but to be a relatively small area of the entire coal region in southeastern Montana. We have visited the area between Birney Day School and Decker, Montana, mapped by Malde and Boyles and, based on our agreement with their mapping boundaries, concur with their findings, though the vegetation and topographic criteria may not be completely applicable for all climates and physiographic provinces in other areas of Montana and the interior western United States.

Malde and Boyles' work is reconnaissance to the extent that no direct measurement of ground water levels, soil moisture, species composition, productivity, or land use was made. However, it is one of two published mappings of alluvial valley floors and provides a good estimate of the nature and extent of such areas in the Powder River Basin of the Northern Great Plains. In the recent past, their efforts have been further confirmed by detailed field mapping of alluvial deposits by the U. S. Geological Survey (Malde, personal communication, 1976).

A similar field reconnaissance study and mapping was recently conducted by the Water Quality Bureau, Montana Department of Health and Environmental Sciences in Dawson, Richland, and Garfield Counties in the Williston Basin of northeastern Montana (Schmidt, 1977). This area, underlain by strippable lignite deposits, has a different physiography, climate, and land use pattern than the area studied by Malde and Boyles. Notable differences include the presence of glacial till and glacial landforms, the occurrence of many saline soils, the existence of larger deposits of gravel which outcrop in valley areas, and recent changes in land use for wheat and hay production. The major difference was the inclusion of somewhat higher terraces in the definition of alluvial valley floors since field surveys gave evidence of subirrigation at higher elevations above the stream channel than were found by Malde and Boyles. Schmidt found significant concentrations of silver sagebrush outside the alluvial valley floor areas. These differences illustrate the regional diversity of alluvial valley floors due to climate, hydrology, and physiography and demonstrate the need for field assessments of alluvial valley floors if one is to be certain of their nature and of their role in local land use patterns.

More specifically, Schmidt found vegetative evidence of shallow ground water on terraces 2.5 meters above the stream channel along small streams and on three-meter

high terraces adjacent to larger streams in the northeastern Montana study area. Along the Yellowstone and Missouri Rivers, somewhat higher terraces exhibit subirrigated vegetative characteristics. Such characteristics are exhibited on nearly all small tributary streams in regions of wheat farming, producing a network of small alluvial valley floors in the headwaters. It appears then that subirrigation of desirable agricultural forage may occur in a slightly larger area in northeastern Montana than in the area of southeastern Montana studied by Malde and Boyles.

Alluvial valley floors in the northeastern Montana study area are shown by Schmidt to exhibit the following additional characteristics relative to those in southeastern Montana: (1) a substantial percentage of valley floors in wheat growing areas are in marsh areas which presently receive extra surface water flow from nearby fields; (2) a substantial percentage of valley floors exhibit slight to severe salinity problems; and (3) larger portions of valley floors are covered, as well as underlain, by thicker, poorly sorted alluvial valley gravels. This last factor can preclude production of sufficient grass for hay production and wildlife usage if the gravel deposit outcrops so as to limit the near-surface water retention capacity and provide poor plant growth medium characteristics. However, the gravels may remain highly productive aquifers and can be important as areas of recharge to downstream alluvial valley floors.

In northeastern Montana, Schmidt found that wheat farmers viewed the drainage areas, including alluvial valley floors, as obstacles to development. This appears to be true also in North Dakota. Over the past ten years the amount of land utilized for wheat has grown while hayed lands have decreased (in northeastern Montana). However, ranchers in Dawson County, Montana, interviewed by Schmidt indicated that the amount of land used for hay production will probably increase in response to higher hay prices and recent lower wheat prices. Thus the amount of alluvial valley floor land used for hay production may also increase in the near future. These types of changes show that assessments of land use in an area must be conducted over several years and supplemented by interviews with farmers and ranchers if the agricultural role of the valleys is to be determined. In any one year, an alluvial valley floor may be used only for unimproved rangeland, wildlife habitat and water drainage. Of course, regardless of land use, the physical or natural characteristics of subirrigated alluvial valley floors probably remain.

Methods Used to Identify Alluvial Valley Floors

This reconnaissance review of alluvial valley floors in existing and proposed surface coal mine areas in the interior western United States was performed utilizing aerial imagery, reconnaissance field work of other agencies, and limited field investigations by the authors. Data from a wide variety of sources were used to develop the conclusions and hypotheses that follow.

A tabulation of the locations (i.e., township, range, and section) of lease tracts for existing and proposed surface coal mines in the interior western United States was provided by the U. S. Bureau of Mines, Intermountain Field Operations Center, Denver, Colorado. Since a field review of the ninety-two identified mine sites was not possible due to time and budgetary constraints, color and color infrared aerial imagery were obtained for the majority of mine sites. U. S. Geological Survey topographic maps, generally at a scale of 1:24,000, were also obtained when available. The aerial imagery facilitated the assessment of relative heights of stream terraces, widths of lowland areas, and vigor and general types of vegetation. The topographic maps served as base maps and permitted more accurate identification of elevations and location of land unit boundaries.

It should be noted that the mine sites considered in this analysis of alluvial valley floors include only those sites scheduled to be in production in the next

few years*. The site location information contains only general descriptions of the leasehold areas to the nearest full section and includes areas that do not contain strippable (i.e., surface mineable) coal. Alluvial valley floor determinations in this report therefore relate specifically to the description for each mine site as listed in Appendix 1. As a result, identified alluvial valley floors may encompass areas other than those underlain by strippable coal. This situation resulted from a lack of detailed information with respect to the locations of strippable coal within the proposed mining areas.

DRAFT

The classification of lowland areas within the leasehold areas as alluvial valley floors was based principally on the following criteria:

(1) underlain by alluvial deposits, where known;
(2) on floodplains and low terraces assumed to be the surface features of alluvial deposits;
(3) in areas exhibiting vigorous vegetative growth in comparison to adjacent areas and thus where subirrigation is likely; and
(4) where valley width is greater than fifteen meters.

Lowland drainage areas, floodplain and low terrace, were assumed to have relatively thick (on the order of a few meters) alluvial deposits. The higher interstream areas and minor alluvial washes are assumed to have thin veneers of alluvium rather than the thicker deposits of water-borne silt and sand materials which are more suitable for growth of forage. Or, they may be sufficiently high and above the water table such that subirrigation does not occur during the dryer months. As noted in the introductory section, in order to support vegetation typical of an alluvial valley floor, the character of this alluvial material must be such that sufficient water is retained for continued plant growth during the dry summer and fall months. Thus areas with a thin veneer of colluvium overlying unweathered strata and gravel-filled areas do not generally qualify as alluvial valley floors since too little soil is present. Also, thick, fine-grained silts or clays (such as lacustrine or playa deposits) may be too impermeable to hold sufficient water for subirrigation of the alluvial valley floor vegetation complex.

Lowland areas more than 1.5 meters (on minor streams) and more than 2.5 meters (on principal streams) in elevation above the water level in the channel, or above the intermittent or ephemeral channel bottom, were generally considered to be out of the alluvial valley floor if infrared aerial photography did not show vigorous vegetative growth during times of lower rainfall and relative to surrounding areas. Similarly, narrow streams incised more than 1.5 meters were generally assumed to indicate a water table too deep to sustain agricultural crops. However, it should be noted that crops grown in some situations could be subirrigated by a ground water system far outside the channel and low terraces of the valley floors. In these instances, the water table may be maintained by bedrock aquifers which recharge the colluvium. While this study did not identify any such cases of significance, the potential for such situations remains.

The minimum fifteen-meter width for an alluvial valley floor designation represents what is perhaps a lower limit of practical "farmability" and geologic stability. In fact, the fifteen-meter width represents a practicable limit to identification of elevations and boundaries on both topographic maps and aerial photographs. It is recognized that, particularly in the Northern Great Plains, some narrower valley floors are stable, subirrigated, and farmed. However, it was assumed for this analysis that these narrower valleys are not essential to agricultural operations. It is likely that the narrower drainages located upstream of the alluvial valley floors serve as wildlife habitats to some degree. Further, the water supplies for

* An original listing of coal mine sites was developed in 1975 as representing western mines to be in production in 1979. That list was corrected by removing some sites that were scheduled to be underground operations and by adding a few existing mines. However, production estimates were not updated.

alluvial valley floors are, most likely, accumulated in and pass through these narrower valleys. Thus their disturbance may be as important as the disturbance of the actual alluvial valley floor. But those upstream areas were not mapped here. Schmidt (1977) did map the upstream wildlife areas in the areas of northeastern Montana he investigated.

Aerial imagery was utilized to assess the relative vigor of vegetation in lowland areas. Relative vigor was shown in color infrared aerial imagery collected during the drier months since the more vigorously growing vegetation is emphasized at this time. When this sign (of growth) is noted, the [illegible] is also identifying areas where shallow ground water is likely to be available or soil moisture is maintained at a level high enough to sustain the vegetation. There is no equally direct indication of the quality of ground water, though large differences in the quality of ground water would be reflected by the composition of vegetation.

It was not possible to assess the species included in the vegetation of subirrigated lowland areas using aerial imagery. Therefore, the methodology incorporated the use of available ground level photographs and other site-specific information gathered by investigators at a number of mine sites*. Therefore the vegetative data presented are neither detailed nor complete since field surveys were not performed.

Alluvial valley floor designations were verified where hay cropping in the valley floor was observed in the aerial imagery. However, occasional difficulties were encountered in identifying alluvial valley floors. Storage reservoirs located in the alluvial valley floors may restrict the extent of downstream flooding and usually increase the subirrigated area by raising the local water table in the vicinity of the impoundment. Such uncertainties in mapping, and others that exist where irrigated lands border the alluvial valley, were not completely resolved during the investigation. However, the effects of these impediments to accurate mapping were considered trivial for the sites evaluated.

The methods used here to identify alluvial valley floors are therefore largely empirical. A definition of a complex interrelationship of geologic, hydrologic, biologic, and topographic conditions that have surface, subsurface, time-related and use-related components was attempted. Since this was done without benefit of adequate field data, it is likely that the definition will improve as field data are compiled.

It is concluded that alluvial valley floors can be mapped in the manner used here with reasonable certainty. Geological, ground water, and vegetative studies would surely refine this analysis, but such investigations would require additional time and field efforts. The reconnaissance methodology utilized for this report may remain a suitable technique for initially identifying alluvial valley floors. Further calibration with ground truth and subsurface data to confirm its accuracy would be desirable. But it is believed that the procedures used adequately identify the alluvial valley floor areas that are subirrigated. What is not identified is the hydrologic system that supports the subirrigation.

---

* Mines for which ground-truth data were available in some form and which had been visited include Black Mesa, Kayenta, Craig, Edna, Energy (1, 2 & 3), Seneca, Colowyo, Absaloka, Big Sky, Circle West, Rosebud (MT), Decker, Savage, Spring Creek, Youngs Creek, Navajo, San Juan, Star Lake, Beulah, Center, Falkirk, Gascoyne, Glenharold, Husky, Indian Head, Velva, Alton, Eagle Butte, Belle Ayr, Big Horn, Black Thunder, Coal Creek, Cordero, Dave Johnston, East Gillette, Jacobs Ranch, Jim Bridger, Lake DeSmet, Medicine Bow, North Rawhide, PSO #1, Rosebud (WY), Seminoe, Sorenson, Welch, Whitney, and Wyodak (See Appendix 1 for locations).

Results of Assessment of Alluvial Valley Floors

Land Surface of Alluvial Valley Floors

Eighty-seven of ninety-two existing or proposed surface coal mine sites were studied. The mine sites are located in an eight-state area (Washington, Arizona, New Mexico, Colorado, Utah, Wyoming, Montana and North Dakota). All states except Washington are loosely grouped under the term "interior western United States".

Using the methodology discussed in the previous section, delineations of alluvial valley floors were denoted on topographic maps or, if topographic maps were not available, on aerial photographs. These then provided the basis for planimeter measurements. Due to space constraints in preparing this report, neither the topographic maps nor the aerial photographs have been reproduced here, but are available for reference at selected locations*.

Table 3 provides the results of the planimeter analysis. The total leased area studied consisted of 369,836 hectares**. Within this area, 11,002 hectares of alluvial valley floors were identified. This amounts to 2.97 percent of the coal mine lease areas described in Appendix 1. Malde and Boyles (1976) determined that just under three percent of the strippable coal reserves of the three-county portion of the Powder River Basin they studied were overlain by alluvial valley floors.

Of the total of eighty-seven mine sites, fifty-nine (68%) contained areas identified as alluvial valley floors. The two mines on Black Mesa, Arizona, were combined and both contained alluvial valley floors. Twelve mine sites of seventeen analyzed in Colorado contained alluvial valley floors. Nine mine sites of the seventeen analyzed in Montana contained areas mapped as alluvial valley floors. Of the seven mine sites studied in New Mexico, only one contained an area designated as alluvial valley floor. Of the eleven mine sites investigated in North Dakota, all but one appeared to involve some part of alluvial valley floors. Neither of the Utah sites involved alluvial valley floors, while in Wyoming twenty-five of the thirty-one mine sites reviewed showed portions of areas designated as alluvial valley floors. The single site in Washington included an alluvial valley floor.

The largest single alluvial valley floor identified was a 1,046 hectare lowland area within the Glenharold Mine "leasehold" (Mine Number 47 or ND-5). However, the area so identified consisted almost entirely of a segment of the alluvial valley floor of the Missouri River. Without the Missouri River alluvial valley floor area, about ten hectares of alluvial valley floors would be involved in the leasehold. It is probable that the coal now mined at the Glenharold Mine does not continue under the Missouri River. This mine site is an example of one where a large area of alluvial valley floor within the leasehold is not indicative of an equally large impact on the amount of strippable coal.

A similar example is at the Craig Mine (Mine Number 5 or C-4), in northwestern Colorado. The coal in this area of the Yampa River alluvial valley floor is reported to be too deep for surface mining (Rural Electrification Administration, 1974). The alluvial valley floor identified for the Navajo Mine (Mine Number 36 or NM-2) is in the San Juan River Valley, north of the northern-most limit of mining to date. The alluvial valley area identified for the Indian Head Mine (Mine Number 49 or ND-7)

---

* Maps are on file in one copy at the Environmental Protection Agency, Office of Energy Activities, 1860 Lincoln St., Denver, CO. Aerial photography is similarly available. Single copies of the aerial photographs have been sent to the appropriate states.

** 1 hectare = .00386 square miles, or 2.4704 acres.

TABLE 3

AREAS OF LAND IDENTIFIED
AS ALLUVIAL VALLEY FLOORS AT EXISTING & PROPOSED
WESTERN COAL MINE SITES[a]

DRAFT

Mine Reference Number[b]		Mine Name	Total area within legal boundaries shown in Appendix 1 (mi^2)	(Hectares)	Area Identified as Alluvial Valley Floor ("AVF") (mi^2)	(hectares)
1.	A-1	Black Mesa	55.10	14,271	0.40	104
	A-2	Kayenta				
2.	C-1	Black Diamond Strip	1.03	267	---[d]	---
3.	C-2	Canadian Strip	0.91	236	0.03	8
4.	C-3	Corley Strip (S&A)	10.37	2,686	---	---
5.	C-4	Craig (Yampa)	48.23	12,492	1.36	352
6.	C-5	Denton Strip	2.07	536	---	---
7.	C-6	Edna Strip	15.30	3,963	0.66	171
8.	C-7	Energy Strip 1,2,3	50.08	12,971	2.93	759
9.	C-8	Crizzly Creek Strip	2.99	774	0.87	225
10.	C-9	Jewel Strip	1.01	262	---	---
11.	C-10	Marr Strip #1	3.85	997	0.16	41
12.	C-11	Nucla Strip	1.97	510	---	---
13.	C-12	Seneca Strip #2				
		(includes Seneca #1)	16.53	4,281	0.25	65
		Seneca #2W	8.73	2,261	.08	21
		Seneca #2Y	2.35	609	.03	8
14.	C-13	Williams Fork Strip	5.34	1,383	1.22	316
15.	C-14	Moon Lake	29.21	7,565	1.75	453
16.	C-15	Colowyo	16.98	4,398	0.36	93
17.	M-1[c]	Absaloka I	(2.99)	(744)	---	---
18.	M-2	Absaloka II	40.21	10,414	1.40	363
19.	M-3	Absaloka III				
		(includes Absaloka I)	24.06	6,232	1.40	363
20.	M-4	Big Sky	8.04	2,082	---	---
21.	M-5	Circle West	77.25	20,008	2.50	648
22.	M-6	Coal Creek	0.92	238	---	---
23.	M-7	Rosebud (Colstrip)	56.22	14,561	1.20	311
24.	M-8	Decker East	5.96	1,544	0.28	72
25.	M-9	Decker North included in Decker #1 (West)--				
26.	M-10	Decker #1 (West)	5.97	1,546	0.12	31
27.	M-11	PM Strip	1.07	277	---	---

a - Analysis performed in Sept. 76; Photography obtained in 1973-76.
b - A = Arizona, C = Colorado, M = Montana
c - Mine #17 is not added in individually since Mine #19 includes the same area.
d - Dashes indicate no alluvial valley floor within tract.

DRAFT

TABLE 3 (Cont'd)

Mine Number[a]		Mine Name	Total Area... (mi²)	(hectares)	"AVF" Area... (mi²)	(hectares)
29.	M-12	East Sarpy Creek	20.71	5,364	0.09	23
30.	M-13	Savage	5.00	1,295	---	---
31.	M-14	Spring Creek	10.99	2,846	0.24	62
32.	M-17	Square Deal	4.19	1,085	---	----
33.	M-15	Storm King	1.07	277	---	---
34.	M-16	Youngs Creek	9.01	2,334	0.02	5
35.	NM-1	McKinley	24.41	6,322	---	---
36.	NM-2	Navajo	88.48	22,916	2.08	539
37.	NM-3	San Juan	12.65	3,276	---	---
38.	NM-4	Star Lake	45.42	11,764	(0)	(0)
		---In need of thorough field investigation to determine role of AVF in Southwest (See text)				
39.	NM-5	Sundance	1.02	264	---	---
40.	NM-6	West York Canyon Strip	17.51	4,535	---	---
42.	NM-8	EPNG	10.22	2,647	---	---
43.	ND-1	Beulah North & South	13.92	3,605	0.05	13
44.	ND-2	Center	5.82	1,507	0.21	54
45.	ND-3	Falkirk (Underwood)	60.89	15,770	1.41	365
46.	ND-4	Gascoyne	7.98	2,067	0.45	117
47.	ND-5	Glenharold	21.43	5,550	4.04	1,046
48.	ND-6	Husky Strip	2.93	759	---	---
49.	ND-7	Indian Head	8.17	2,116	0.16	41
50.	ND-8	Larson (Noonan)	10.04	2,600	0.25	65
51.	ND-9	Nelson	0.99	256	0.28	72
53.	ND-11	Sprecker	1.00	259	0.07	18
54.	ND-12	Velva	5.98	1,549	0.07	18
55.	U-1	Alton	64.89	16,807	---	---
56.	U-2	Energy Strip	4.20	1,088	---	---
61.	WA-2	Centralia	0.95	246	0.37	96
62.	WY-1	Eagle Butte(Belle Ayr North)	7.64	1,979	0.11	28
63.	WY-2	Belle Ayr (South)	11.28	2,922	1.16	300
64.	WY-3	Big Horn	6.95	1,800	0.94	243
65.	WY-4	Black Butte	35.38	9,163	0.02	5
66.	WY-5	Black Thunder	12.99	3,364	0.06	16
67.	WY-6	Buckskin	2.07	536	0.05	13
68.	WY-7	Caballo	15.24	3,947	0.67	174
70.	WY-9	Cordero	11.96	3,098	0.33	85
71.	WY-10	Dave Johnston	37.61	9,741	1.45	376
72.	WY-11	East Antelope	1.00	259	---	---
73.	WY-12	East Gillette	11.63	3,012	2.61	676
74.	WY-13	Elko	0.97	251	---	---

a - NM = New Mexico, ND = North Dakota, U = Utah, WA = Washington, WY = Wyoming

DRAFT

TABLE 3 (Cont'd)

Mine Number		Mine Name	Total Area... (mi^2)	(hectares)	"AVF" Area... (mi^2)	(hectares)
75.	WY-14	FMC	17.79	4,608	---	---
76.	WY-15	Jacobs Ranch	10.21	2,644	0.28	72
77.	WY-16	Grass Creek	1.15	298	---	---
78.	WY-17	Jim Bridger	41.28	10,692	0.05	13
80.	WY-18	Lake De Smet	37.63	9,746	0.58	150
81.	WY-19	Medicine Bow	27.74	7,185	0.22	57
82.	WY-20	Muddy Creek	1.98	513	0.10	26
83.	WY-21	North Rawhide	22.95	5,944	2.49	645
84.	WY-22	P.S.O.#1	1.01	262	0.06	16
85.	WY-23	Rimrock	21.36	5,532	0.34	88
86.	WY-24	Rochelle	14.89	3,856	0.11	28
87.	WY-25	Rosebud	17.95	4,649	0.11	28
88.	WY-26	Seminoe #1	19.37	5,017	0.12	31
89.	WY-27	Seminoe #2	24.60	6,371	---	---
90.	WY-28	Sorenson & Elkol	38.53	9,979	---	---
93.	WY-29	Twin Creek	8.78	2,274	0.89	230
94.	WY-30	Welch	3.05	790	0.89	230
95.	WY-31	Whitney	3.29	852	1.22	316
96.	WY-32	Wyodak	8.04	2,082	0.83	215
			1427.94	369,836	42.48	11,002

is likewise located north of the coal presently surface mineable and within a drainage channel not likely to be mined. The Welch Mine (Mine Number 94 or WY-30) is not located in the Tongue River alluvial valley floor, but the description of the lease area includes 8.89 hectares of alluvial valley floor.

On the other hand, the Wyodak Mine (Mine Number 96 or WY-32) is currently located entirely within the alluvial valley floor of Donkey Creek. The Whitney Mine (Mine Number 95 or WY-31) is proposed to be located partially within an alluvial valley floor (37% of lease tract is an alluvial valley floor). Belle Ayr Mine (Mine Number 63 or WY-2) is operating in an alluvial valley floor. The Big Horn Mine (Mine Number 64 or WY-3) has involved the alluvial valley floor of a stream tributary to the Tongue River and lies adjacent to the alluvial valley floor of the Tongue River. As we shall explain in the next section, more area than that suggested by Table 3 may be affected by avoidance of alluvial valley floors during mining in cases where the mines are adjacent to an otherwise impact the hydrology of subirrigated alluvial valley floors.

Since valley areas examined at mine sites located in more arid climates did not show equal evidence of year-around subirrigation (equal to that shown in the semi-arid areas of the Northern Great Plains), only a few alluvial valley floors were identified for New Mexico, Arizona, Utah, and southwestern Wyoming. This reconnaissance investigation did not find the vegetation of most drainages in New Mexico, Arizona, Utah, or southwestern Wyoming to show vigorous growth during the dry months. However, it may be that the spring and winter precipitation in these lowlands is sufficient for enough forage to be produced at those times to make a significant positive impact on grazing. The lowland areas in the arid climates may be important by virtue of their providing some degree of protection from wind. These attributes of alluvial valley floors do not appear to be addressed in the legislative proposals and were not measured during the assessment described herein. A detailed field study of the role of lowland drainage areas in agriculture and of the critical geohydrologic factors supporting that role is especially needed in the New Mexico, Arizona, and southwestern Wyoming coal regions.

It is noted again that the percent "imposition", or surface conflict between alluvial valley floors and the surface of coal mine tracts cannot be translated directly to coal production "losses", since loss is determined by the technology available to mine the particular coal under site-specific geologic and hydrologic circumstances. The data in Table 3 could be directly translated into an effect on shallow coal only if, for simplicity, it were assumed that (1) all alluvial valley floors on mine leaseholds overlie shallow coal; (2) no coal underlying an alluvial valley floor can be mined; (3) the coal were evenly distributed over the tract such that the percentage of coal affected was the same as the percentage of land in the alluvial valley floor, and (4) mining of coal adjacent to the alluvial valley floor was compatible with protection of the valley's hydrologic system. (The second assumption would be based on a further assumption that the subirrigated alluvial valley floors could not be reclaimed.) Under these assumptions the percentage of coal removed from near-future production on the leasehold would be 2.97 percent. However, that translation may be misleading because additional coal might be affected because of its relationship with the subirrigated alluvial valley floor; or less coal might be affected if the valley floor could be reclaimed. The following section attempts to project impacts of a ban on the mining of alluvial valley floors on the shallow coal resource. This will be done by analyses of a few hypothetical, yet reasonable, geologic-hydrologic situations. A more comprehensive analysis would require the evaluation of site-specific circumstances and field measurements to determine what mining technologies might be utilized and how the mining operation might be developed to protect the integrity of the alluvial valley floor.

The point remains though, that the percentages that may be calculated to show areas of land overlying surface mineable coal based on the data in Table 3 do not represent the amount of coal that will be affected if reclamation after mining these and adjacent lands cannot reestablish the critical hydrologic balance that supports the alluvial valley floor.

Hypothetical Coal Mining Situations in Alluvial Valley Floors

In order to better describe the amount of strippable coal affected by restrictions on mining of alluvial valley floors, this section investigates selected hypothetical mining situations in alluvial valley floors. The situations examined in which maintenance of pit wall stability adjacent to alluvial valley floors may require setting aside additional amounts of coal. Also examined are situations in which hydrologic complexity appears to preclude successful reclamation of affected alluvial valley floors. It must be remembered that the [illegible] that follow are based not on exhaustive field investigations, but rather [illegible] attempts to generalize surface and subsurface conditions according to principles [illegible] hydrology and geology. While there is confidence that situations such as these exist, field investigations may show them to be rare, oversimplified, or even too complex. But whatever the conditions are, they cannot be ignored or their analysis postponed since judgements as to their compatibility with surface mining of coal must be made now.

We have assumed for purposes of calculations that an "average" alluvial valley floor is 200 meters wide and, as noted above, that any coal under the floors must be left undisturbed. In certain cases, coal may be removed up to the border of the alluvial valley floor. Such cases might exist if the coal were relatively thin (three to six meters for western coal), covered by thin yet sufficient overburden to permit regrading to a similar elevation and topography, and in relatively simple hydrologic situations such as a thick alluvial aquifer that can be reestablished through selective placement of spoiled overburden. In other cases, pit wall stability or perhaps maintenance of a stream may require leaving a coal barrier outside the alluvial valley floor, thereby increasing the amount of "lost" coal. We have assumed the pit wall stability situation to be one where pit wall stability requires maintenance of a 45° slope (1:1) on the active highwall such that 60 meters of the coal seam extending away from each side of the alluvial valley could not be mined. The 60-meter value is obtained by assuming that the mine pit will be 60 meters deep and that a 1:1 highwall slope will be maintained. Since the coal lies along the base of the right triangle (45°) created by the 1:1 slope, at least 60 meters of the coal seam would be left in place. This increases "lost" coal from the 200-meter width lying directly under the alluvial valley floor to 320 meters, or a 60 percent increase in the amount of coal that would not be mined in this situation. Based then on the three percent value calculated in the initial analysis of alluvial valley floors overlying coal lands (Table 3), this "pit wall stability" situation would increase the amount of coal "lost" or "withdrawn" to about five percent.

Additional coal may also be lost if the coal in an alluvial valley floor is covered by relatively thin overburden, since this coal may offset the higher extraction costs of coal lying outside the alluvial valley floor and covered by thicker overburden. That is, the coal overlain by thin overburden in the alluvial valley is relatively cheap to mine and can be used to balance the higher expense of extracting coal lying under thick overburden in the highlands. If this overburden factor enters into consideration when marketing coal from a leasehold and the "pit wall stability" situation is also encountered, the amount of coal "lost" could double to about ten percent. Note again, that these calculations are hypothetical. Actual field situations would have to be studied before firm estimates of the amount of coal lost could be made.

In other extreme cases, mining in the entire drainage area could be prohibited unless it were deemed possible to maintain and reestablish critical geohydrologic characteristics such as effective aquicludes* and water quality. Such would be the case if reclamation could not reestablish the essential functions of an alluvial valley floor supported by a perched water table (thus lowering the water table), or if

* Aquicludes: Relatively impermeable rock capable of absorbing water slowly, but functions as an upper or lower boundary to an aquifer. Does not transmit ground water rapidly enough to supply a well or spring.

mining caused the plant growth medium to change significantly in permeability and chemistry, thus affecting plant productivity, ground cover density, or species composition. Of course, if the impact of mining were one of deterioration of water quality to the point of adversely affecting water use, no coal seams that are hydrologically upgradient of alluvial valley floors, or which are related to the subirrigated system could be mined without reducing the productivity and use of the alluvial valley floor to a degree proportional with the watershed area affected. It would be inappropriate to mine such areas until pollution control technology was available, regardless of other potentials for successful grading, revegetation, or local subirrigation of the mined area. Finally, if a number of individual alluvial valley floors occurred on one mine tract, it is likely that avoidance of these areas would result in isolated, small blocks of coal that might be uneconomical to mine. In these examples, the entire leasehold could be determined uneconomical to mine.

A better estimate of the impacts of mining alluvial valley floors might be made by examining a number of f situations that appear characteristic of the western United States coal regions. Emphasis in the examination is on the geologic and hydrologic situation existing in, and in the immediate vicinity of, the subirrigated alluvial valley floor.

Figure 1 portrays the hydrologic cycle in a simplified form. It depicts how water may become available to vegetation as precipitation, as overland flow in the unsaturated and the capillary zones, in the saturated zone beneath the water table, or as locally "perched" water.

Figure 2 shows the concept of multi-aquifer systems where waterbearing strata are separated by confining beds or aquicludes containing semi-permeable strata. The aquifers may have completely independent flow systems providing significantly different piezometric surfaces (i.e., height to which water will rise in a well) and flow directions. Aquicludes permit minor amounts of water to pass. The permeability of aquifers may involve connected pore space formed during deposition and/or secondary permeability (i.e., fracture permeability) formed after deposition. The shallow coals of the interior western United States gain most of their permeability, and therefore their role as part of the shallow aquifer system, from fracturing. Blasting of overburden and coal during mining may increase the permeability both of aquifers and aquicludes. This artificial fracturing is important when aquicludes immediately beneath the coal separate aquifers with significantly different water pressures or piezometric heads, or strata containing water of differing quality.

It appears likely that in many cases subirrigation in an alluvial valley floor occurs through a single, shallow, unconfined aquifer. This single aquifer includes stream alluvium comprised of gravels, sands, silts, and thin clays. In the coal regions of the western United States, this shallow aquifer may also include a coal seam and associated sandy strata. The first case, shown in Figure 2, depicts a situation where ground water is discharged to a stream (i.e., a gaining or effluent stream). Figure 3 illustrates a case of recharge where the stream recharges a ground water aquifer (i.e., a losing or influent stream) and hence provides shallow waters for the alluvial valley floors.

Figures 4, 5, and 6 illustrate three simplified geohydrologic situations that could exist in alluvial valley floors. Using these hypothetical situations, we have attempted to assess the impact of mining and reclamation on the hydrologic system and, based upon this analysis, tried to ascertain whether mining would be compatible with the objective of mining only where reestablishment of vegetative productivity and species composition was assured. Figure 4 represents a situation with a single coal seam which serves as the bottom portion of a shallow aquifer system. The aquifer includes sandstone, siltstone, gravel, and alluvium. The aquifer is unconfined and is assumed to discharge some water to the stream through the alluvium. Reclamation of this area after surface mining of the coal at a mine of typical size (less than 1,000 hectares) should result in the water table returning to pre-mining levels. However, if multiple mining operations cause the entire coal-sandstone aquifer to be disturbed throughout the regional watershed so as to drastically change the permea-

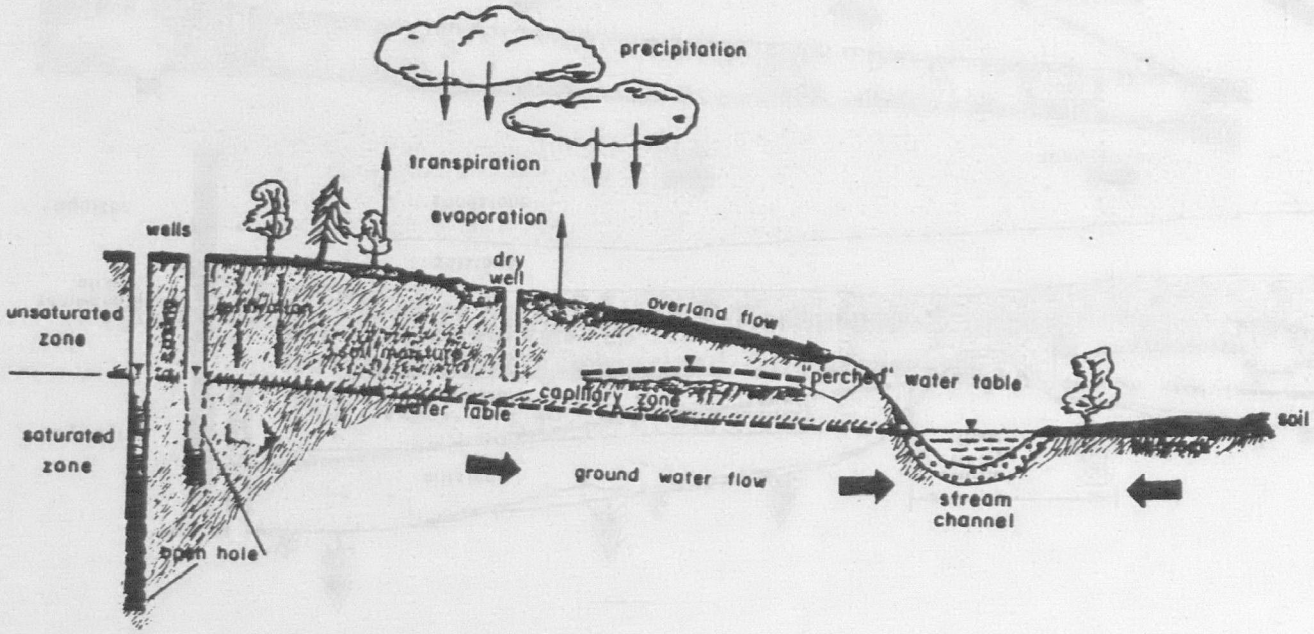

Figure 1 Simple Precipitation-Runoff-Infiltration Cycle. Unconfined Ground Water Aquifer.
(Semi-confining strata create "perched" water table conditions)

DRAFT

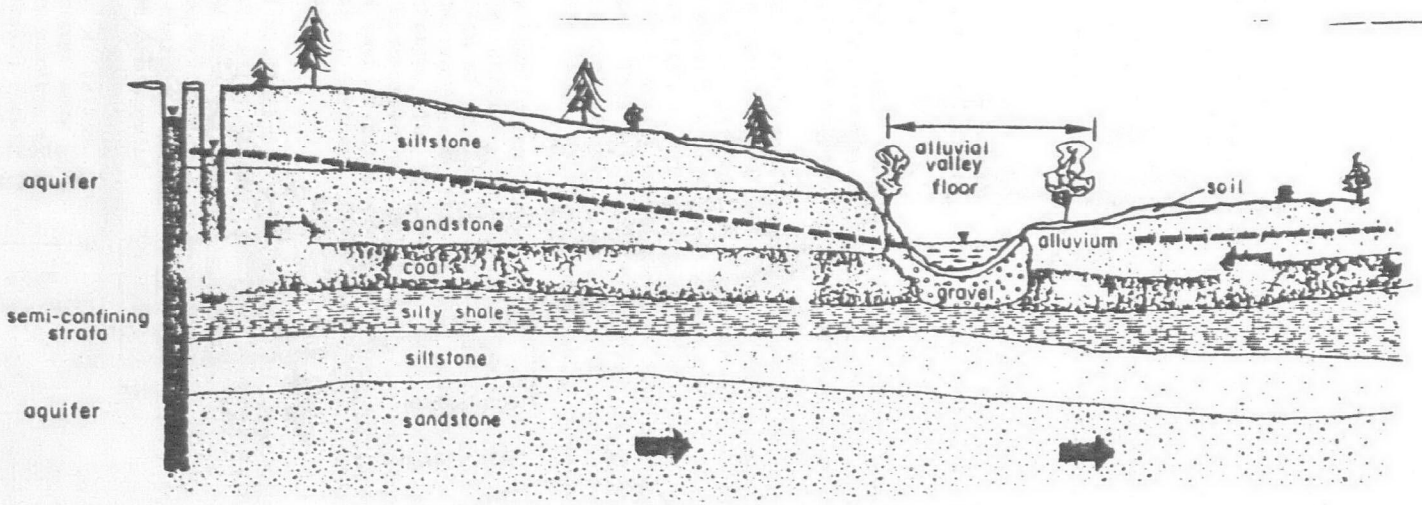

Figure 2 Simple Two Aquifer Ground Water System Showing Subirrigated Alluvial Valley Floor.

(Ground water discharges to stream alluvium and gravel. Water in lower aquifer well rises above that of upper, unconfined aquifer)

DRAFT

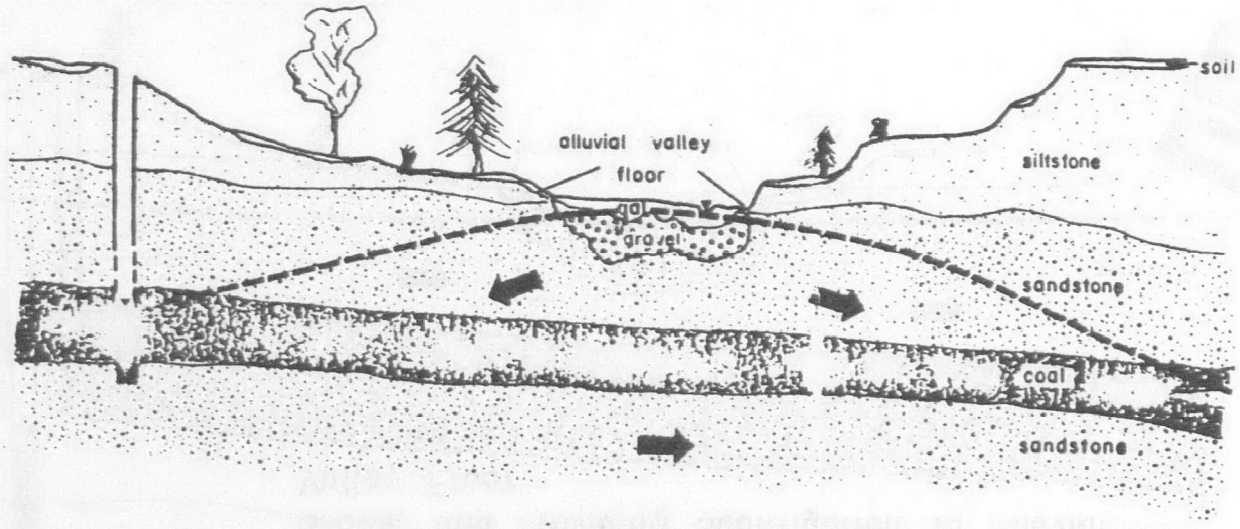

Figure 3 Effluent (Losing) Stream Recharges Ground Water Aquifer Comprised Of Sandstone And Coal. ("qal" denotes alluvium)

DRAFT

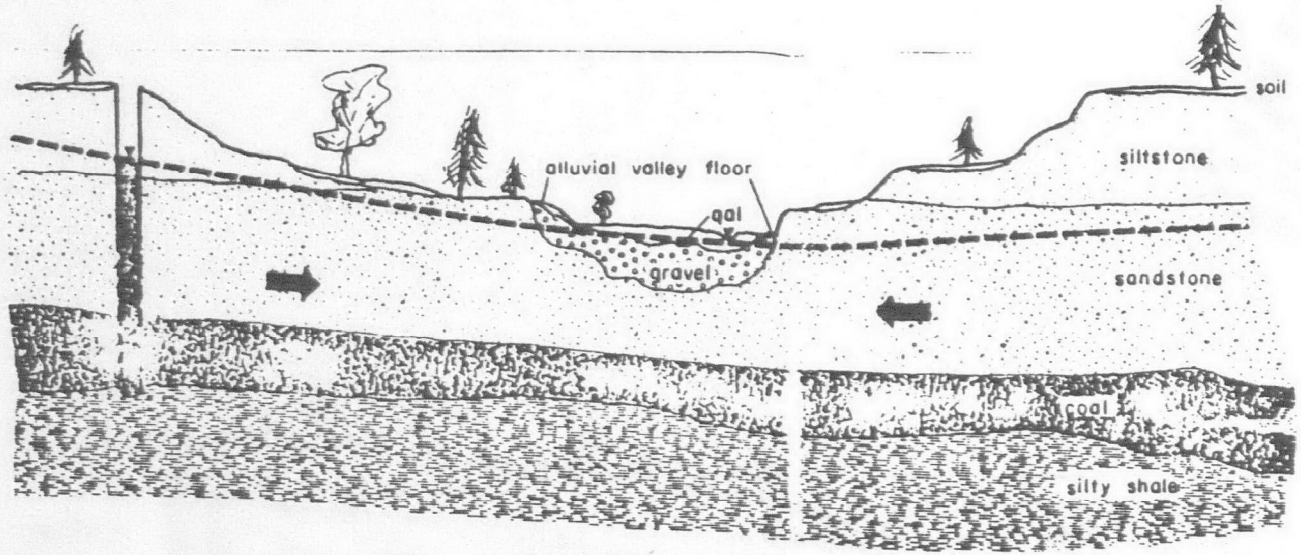

Figure 4 Single Sandstone, Siltstone And Coal Aquifer Intercepted By Stream Alluvium (qal) And Gravel And Providing Subirrigation To Alluvial Valley Floor.

DRAFT

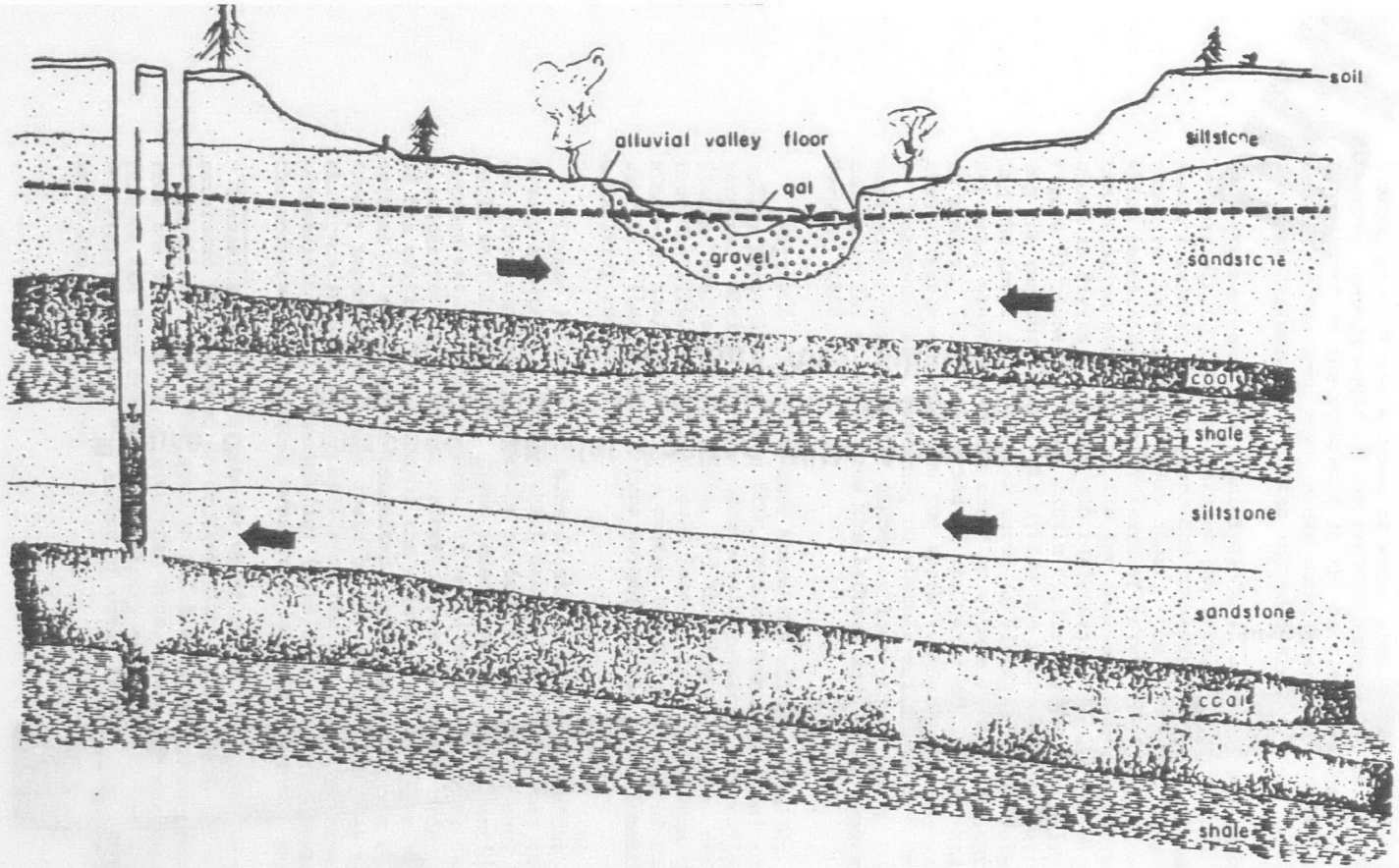

Figure 5 **Multiple Sandstone, Siltstone And Coal Aquifers With Differing Directions Of Flow And Ground Water Pressures.** (Upper aquifer supports alluvial (qal) aquifer and the alluvial valley floor)

DRAFT

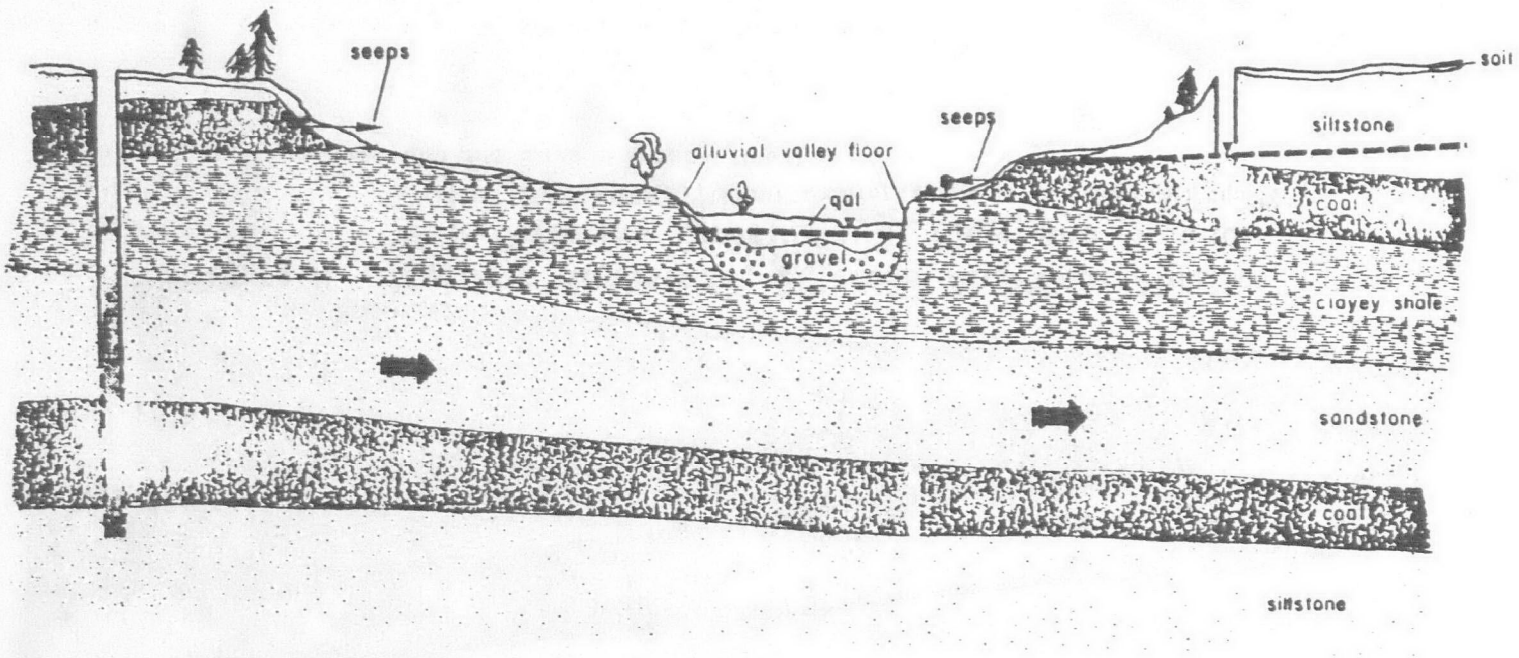

Figure 6 "Perched" Alluvial Aquifer With Alluvium (qal) And Gravel Supplied By Upstream Runoff And Seeps Issuing From Upper Coal And Siltstone Aquifer.

DRAFT

bility of recharge and discharge areas, the post-mining water table might change significantly. This potential for cumulative impacts from more than one mine necessitates the initial qualification on size of 1,000 hectares.

If appropriate water quality is maintained after reclamation, the valley area shown in Figure 4 would appear reclaimable at least with regard to reestablishment of the ground water system in terms of flow, depth to water, quantity of flow, and quality. Deposition of spoils by draglines and return of the post-mining topography to an average elevation about the same as before mining should result in an aquifer transmissivity* and a depth of water about equal to that prior to mining. Of remaining concern would be the reestablishment of the capillary zone** and the field capacity*** of the rock/soil in the root zone. These do appear to have been reestablished in some mined areas outside alluvial valley floors where adequate soil has been redistributed on the regraded areas.

DRAFT

Figure 5 portrays a multiple "coal aquifer" system which is also considered to be possible in certain areas of the interior West's coal regions. The figure shows again a gaining stream where the unconfined upper coal-sandstone aquifer supplies water to the alluvial valley floor. The lower coal aquifer is confined by the shale which permits only minor leakage of water. The direction of leakage depends upon the relative pressures in the two coal-sandstone aquifers. Similar to the case shown in Figure 4, mining and reclamation of only the upper coal seam (as shown in Figure 5) might result in little disturbance to the alluvial aquifer system providing the regional hydrologic system and water quality were maintained. However, mining the lower coal seam (as shown in Figure 5) could result in a combination of aquifer water pressures which could be either lower or higher than that existing prior to mining. If the elevation of the water table were changed significantly, vegetation formerly dependent on the upper aquifer water for growth could be "waterlogged" or "waterstarved", depending on whether water pressure in the underlying aquifer were either significantly higher or lower than that of the upper aquifer. The discharge to the alluvium from the bedrock aquifer is typical of the area near Gillette, Wyoming (USGS, 1974).

Figure 6 presents a case where the alluvial aquifer subirrigating the alluvial valley floor is separated from regional sandstone-coal aquifers by the clayey shale stratum. Mining of these areas would result in disruption of the natural semi-confining layer of clayey shale. If this layer were not restored, it is conceivable that the alluvial aquifer would lose or gain water from the backfilled area of the mined-out coal leading to a change in the elevation of the water table. Again, whether a loss or gain occurs depends on the potentiometric level of the water into underlying strata.

Figure 7 depicts in more detail an alluvial aquifer containing lenses of relatively impermeable strata which create "perched" water tables which support grasses and other vegetation suitable as forage. Mining of coal beneath such an aquifer would most likely break these lenses and, in the situation portrayed, permit the perched water table to drop. It would be necessary to deposit spoiled overburden in a selective manner and to reform compact lenses in order to attempt reestablishment of the critical functions of the alluvial valley floor in this situation. It is the opinion of some experts consulted during this analysis that recreation of the relatively impermeable strata would be impossible. Studies by Rahn (1976) indicate that the truck/scraper-dumped spoils at the Big Horn Mine have a laboratory coefficient of permeability of 0.16 meters/day (4gpd/ft). This is essentially equal to that of the undisturbed sandstone overburden measured nearby. Since this is at the high end

---

* Transmissivity: The rate at which water in an aquifer is transmitted through the saturated thickness of an aquifer with a unit width and a unit hydraulic gradient.
** Capillary zone: The zone in which water migrates upward a characteristic distance from the water table or saturated zone, where the distance is dictated by the structure of the pore spaces and chemistry of the fluid and the solid.
*** Field capacity: The amount of water held in the soil after the gravitational water has drained away.

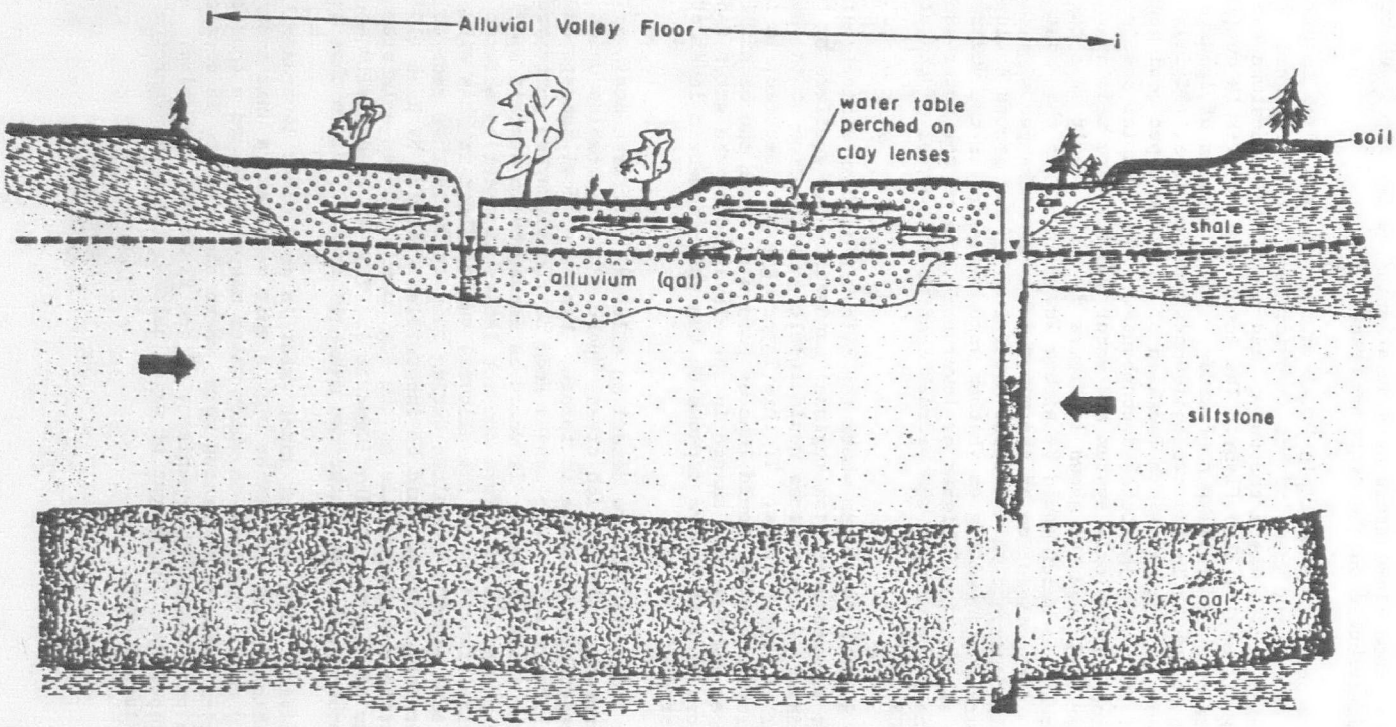

Figure 7 Detailed Section Across Alluvial Valley Floor And Alluvial Aquifer Showing Locally Perched Water Tables.

DRAFT

of permeabilities expected of poor aquifers or aquicludes (which may have permeabilities of 1.0 to 0.01 gpd/ft or 0.04 to 0.0004 meters/day), it is suggested that more compaction than that performed at Big Horn is necessary to achieve lower permeabilities. This compaction over and above that performed at the Big Horn Mine appears necessary to recreate zones of "perched" water.

The water supply to the alluvial valley floor (as shown in Figure 7) could also be the alluvial aquifer (i.e., underflow) and this would require that the a[illegible] of recharge located upstream would have to be protected. This locally compl[illegible] situation could also exist in any of the situations shown in previous fi[illegible]

Of the three hydrologic situations shown in Figures 4, 5, [illegible] de-tailed perched system of Figure 7, the multiple aquifer system [illegible] Figure 5 appears the most difficult to reestablish. The situation shown [illegible] Figure 6 is also difficult to reestablish. Both cases require the recreation of an effective semi-confining layer, a reclamation practice not yet attempted on such a scale. The perched aquifer system of Figure 7 could be difficult to reestablish for the same reason. The single unconfined aquifer system shown in Figure 4 appears to have the highest probability for reestablishment.

Based upon many assumptions which are given below, we suggest that in the situation shown in Figure 4 no coal would be removed from production because the critical features of the hydrologic system could be reestablished. The situation shown in Figure 5 would necessitate leaving the second, deeper coal seam in place if pressures of ground water were sufficiently out of balance and the combined post-mining pressure (or water table elevation) was deemed to adversely affect the subirrigation system. The situation portrayed in Figure 6 would require leaving the clayey shale in the vicinity of the alluvial valley floor in place and thus would require leaving sufficient coal under the shale to maintain the confining bed. The upper coal would be mineable. In the case of the alluvial valley floor in Figure 7, we suggest that the hydrologic system could be reestablished and that all the coal shown could be extracted if very selective placement and additional compaction of spoil in a manner not now used in western surface mining were required.

In order to judge the probability for successful reclamation of these hypothetical alluvial valley floors and reestablishment of their essential functions, we have made the following assumptions:

1. The post-mining topography and elevation would be very similar to that existing prior to mining such that the approximate distance from the ground surface to the water table was retained;

2. The post-mining stream gradient (and flow) achieved the same quasi-stable equilibrium state existing prior to mining in terms of erosion and sedimentation;

3. A suitable plant growth medium was reestablished after mining;

4. Vegetative productivity and species composition were reestablished after mining;

5. The areas of ground water recharge were not modified;

6. Water quality was maintained; and

7. It would not be economically feasible to reestablish aquicludes over large areas.

The first two assumptions would not be correct in instances where the overburden thickness is thin relative to coal thickness. In such cases, post-mining topography would be lowered by many meters. Those situations have not been examined on a mine-by-mine basis but must instead be examined on a regional basis that encompasses entire basins.

Not specifically addressed in detail as yet are disturbances to areas of ground water recharge for alluvial valley floors. Obviously, water providing subirrigation must be introduced into the alluvial and bedrock aquifers at some location. Little surface recharge to most alluvial aquifers takes place in the immediate alluvial valley floor area of any one mine. Therefore, one may envision that the aquifers shown in the preceding cross sections are connected to areas into which sufficient precipitation infiltrates to replenish the ground water. And the areas shown in the Figures are connected to surface watersheds which collect water during periods of high flow that can be spread over the alluvial valley floors. If these upstream areas of recharge are disturbed, the water supply in the alluvial valley floor may be significantly affected.

DRAFT

Nor has the topography of the alluvial valley floor been adequately addressed. Surface water flow may be sufficient to supply valley floor vegetation. In all cases shown in the preceding figures, it will be necessary to recreate a low flood plain and a stable drainage system after mining. The flood plain may be necessary for periodic flooding and simple spreading of flood waters to restore soil moisture. The stable drainage system is necessary to control erosion and sedimentation. Stability was the aspect of alluvial valley floors of greatest concern to members of the "Study Committee on the Potential for Rehabilitating Lands Surface Mined for Coal in the Western United States" (National Academy of Sciences, 1974, p. 45). Hadley and King (1977) are developing a paper which identifies the problem of recreating a quasi-equilibrium* in stream channels once the longitudinal profile is disturbed during surface mining.

The most complete published data describing an alluvial valley floor situation known to the authors is that of Van Voast and Hedges (1975). Though Van Voast and Hedges' objective did not include an assessment of agriculturally-important subirrigated areas, the hydrologic cross sections developed and analyses performed by them are pertinent to this analysis of alluvial valley floors. Figure 8 is a topographic map showing the alluvial valley floor identified by this reconnaissance study along the East Fork of Armells Creek and the locations of three cross sections developed by Van Voast and Hedges. The cross sections are reproduced, in generalized form, in Figure 9. Cross sections B-B' and C-C' intersect the alluvial valley floor of the East Fork of Armells Creek.

The East Fork of Armells Creek is described by Van Voast and Hedges as intermittent in the area west of Colstrip, Montana, and perennial downstream of the town. Immediately west of the north-south road the East Fork is somewhat incised, and the subirrigated alluvial valley floor is relatively narrow. During two field inspections conducted in 1976, no hay cropping was observed in the area shown.

Two surface-mineable coal seams exist in the Colstrip area, an upper Rosebud seam and a lower McKay seam, separated by "interburden" ranging in thickness from one to twenty meters. Van Voast and Hedges describe the interburden as including local aquifers of sandstone and clayey silt. Water has been obtained from aquifers below the McKay seam for use at Colstrip. Water levels in the alluvium and McKay coal seam near the East Fork of Armells Creek are estimated by Van Voast and Hedges to fluctuate about one meter between the spring and early summer recharge periods, and the fall.

Van Voast and Hedges have concluded that the water in the coal-seam aquifers is at least partially confined and that the alluvium along the East Fork of Armells Creek receives discharge from these aquifers. This water then flows downstream in the alluvial aquifer. However, in cross section A-A' (Figure 9), the Rosebud Coal is reported to be recharged by the alluvium. This cross section is located west of

---

* The state of balance or grade in a stream cross section whereby conditions of approximate equilibirium tend to be established in a reach of the stream as soon as a more or less smooth longitudinal profile has been established, even though downcutting may continue (American Geological Institute, 1972).

Figure 8 Topographic Map Showing Alluvial Valley Floor And Hydrologic-Geologic Profiles Across East Fork Armells Creek Near Colstrip, Southeastern Montana.
(Profiles measured by [illegible])

DRAFT

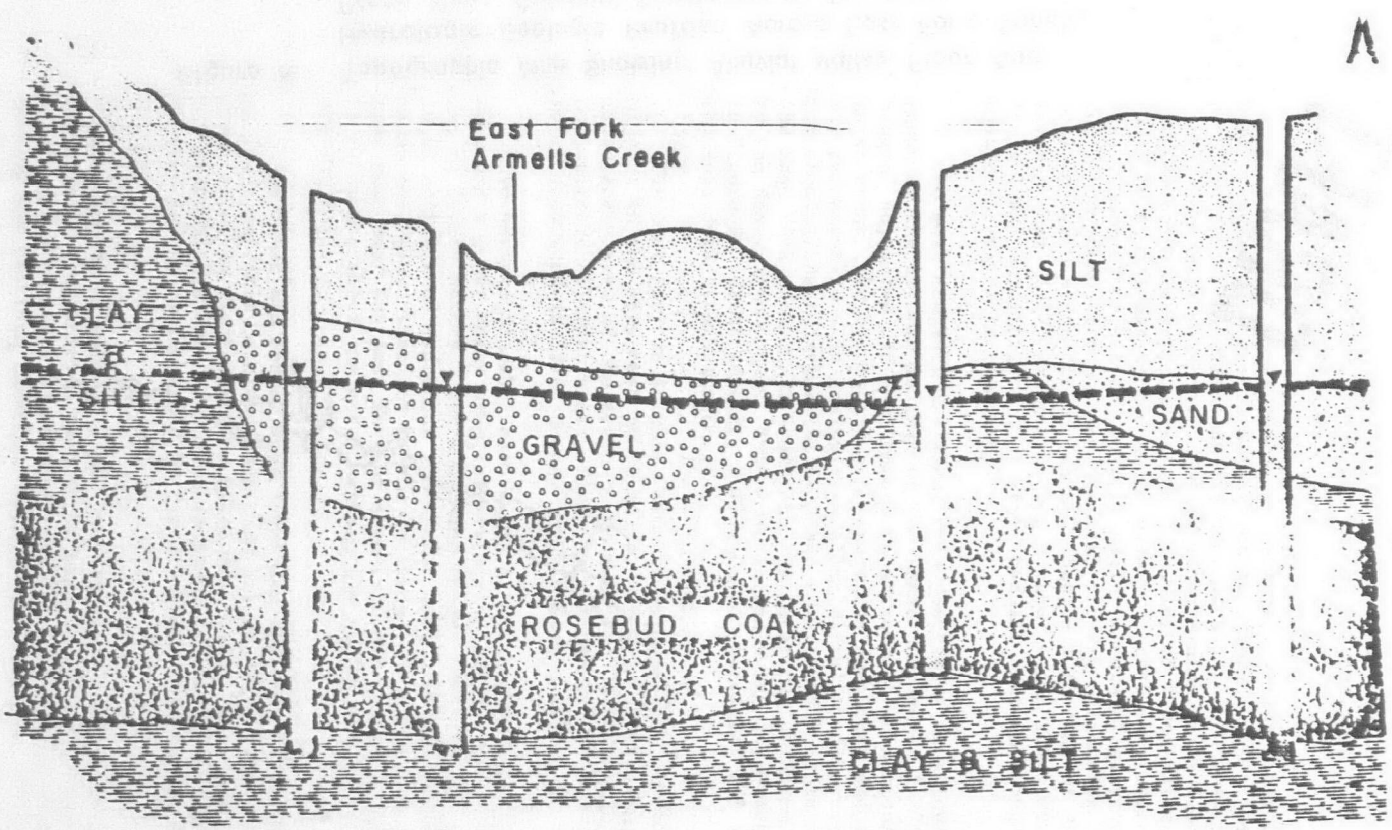

Figure 9 Three Hydrologic - Geologic Profiles Across East Fork Armells Creek And Location Of Alluvial Valley Floor.
(Profile data from Van Voast and Hedges, 1975. Locations of profiles shown on Figure 8) not to scale

DRAFT

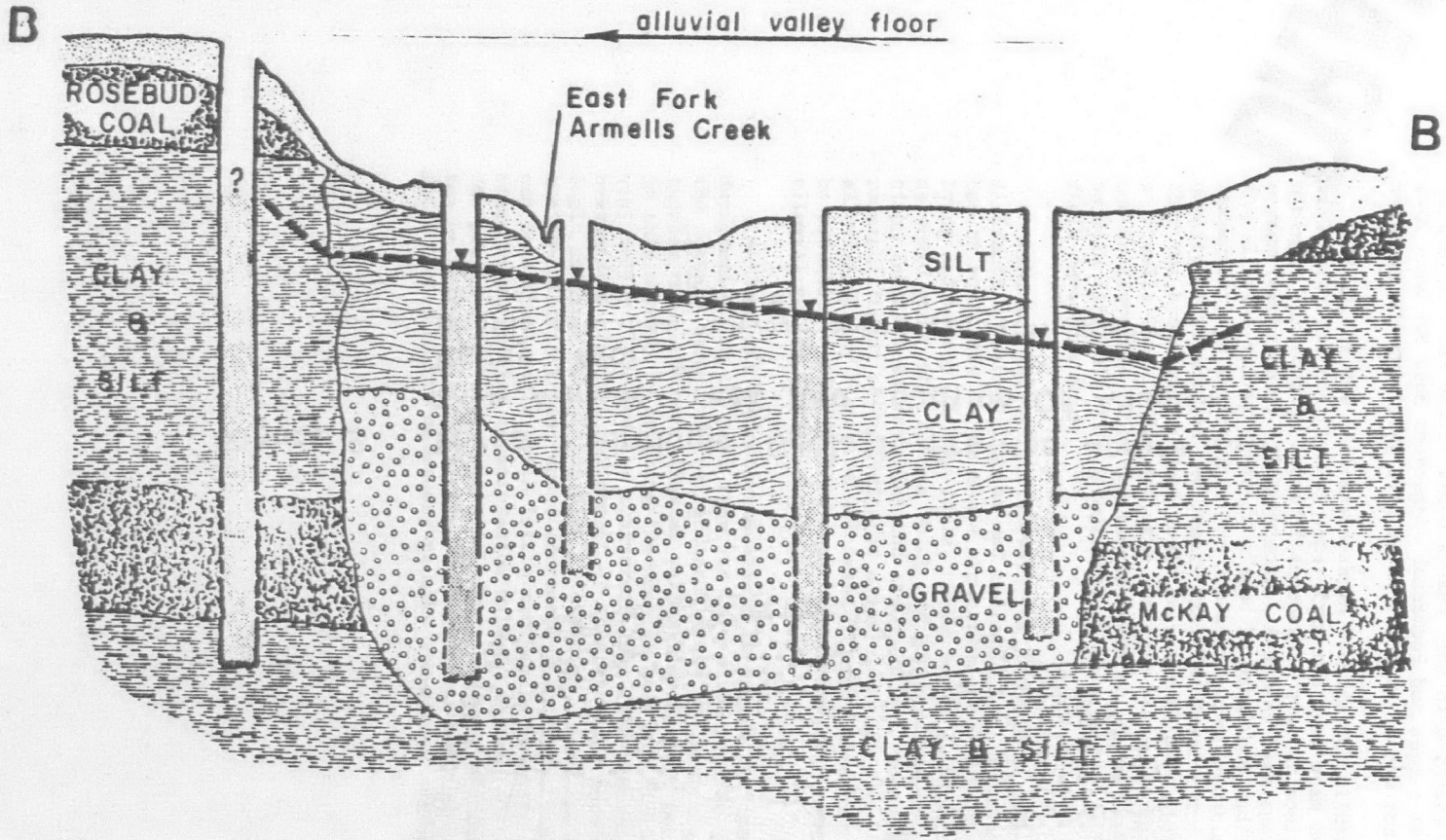

Figure 9 Three Hydrologic - Geologic Profiles Across East Fork Armells Creek And Location Of Alluvial Valley Floor.
(Profile data from VanVoast and Hedges, 1975. Locations of profiles shown on Figure 8) not to scale

DRAFT

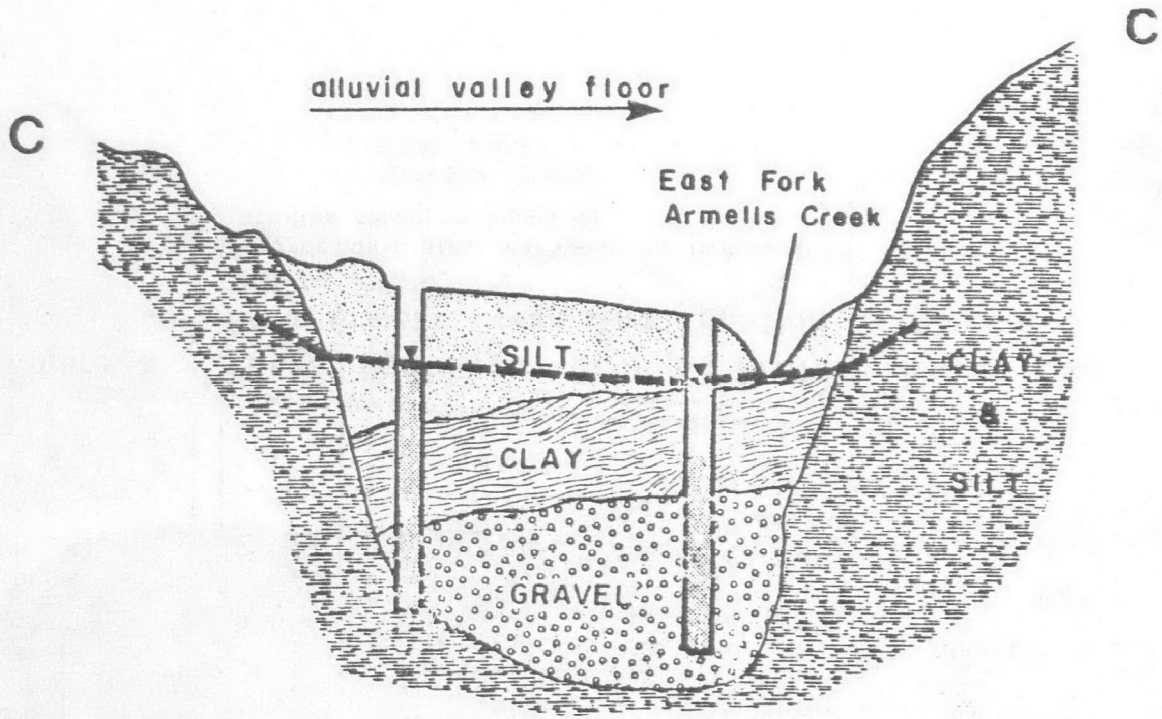

Figure 9 Three Hydrologic - Geologic Profiles Across East Fork Armells Creek And Location Of Alluvial Valley Floor.
(Profile data from Van Voast and Hedges, 1975. Locations of profiles shown on Figure 8) not to scale

DRAFT

the mapped alluvial valley floor. In cross section B-B', the gravels are recharged by discharges from the underlying McKay coal, indirectly by discharges from the Rosebud coal, and by surface flow along the channel. Farther downstream and out of the surface-mineable coal area (cross section C-C'), the creek receives discharge from the gravels and adjacent consolidated materials. Thus the stream alluvium loses water in the upstream reaches and gains water from the bedrock materials through most of the alluvial valley floor areas. The clay layers shown in cross sections B-B' and C-C' have not been thoroughly described but appear to have potential to hold some water in the overlying silt so as to be available for subirrigation.

Mining of the coal seams shown outside the alluvial valley floor in Figure 9 will interrupt the flow of water from the coal seam aquifers to the alluvium during mining. Intercepted water of acceptable quality could be discharged back into the stream (downstream) during mining. Assuming that spoiled overburden removed outside the alluvial valley floor is placed by draglines and/or scrapers (without additional compaction) to approximate the pre-mining configuration of the surface and that water quality is maintained, we concur with Van Voast's and Hedges' preliminary findings that the hydrologic system could be reestablished along the margins of the East Fork of Armells Creek. However, the geologic system in the creek itself should probably not be disturbed since the reestablishment of the semi-confining clay layers would be more difficult. Final opinions in this matter would be dependent on more detailed field investigations.

Alluvial valley floors overlying a confined coal aquifer appear to create a most difficult situation to mine and reclaim if it is necessary to recreate the confining bed or aquiclude. Thus these situations pose problems for the extraction of underlying and nearby shallow coals. Substantial lowering of the land surface (elevation) as would occur when mining thick coals under thin overburden could also create situations (shallow water tables and steep surface channels) creating impediments to the reestablishment of subirrigated alluvial valley floors. The greater the area of alluvial valley floors on a leasehold, the greater the likelihood that it will not be possible to mine shallow coal by surface methods without adverse impacts on the alluvial valley floors.

While it is obviously necessary to assess the impacts of alluvial valley floor designations on the coal reserves in a site-specific manner, it is suggested that the average amount of coal affected would be about ten percent on a lease tract containing coal under an alluvial valley floor. This ten percent was developed earlier in this section by assuming the need to maintain highwall stability along the alluvial valley floor and the concurrent loss (for economic reasons) of coal under thick overburden. Further refinement of this estimate necessitates additional geohydrologic and specific mining plan information. Such refinement, presently necessary on a site-specific basis, could decrease or increase this estimate. Obviously there can be situations in which little coal could be mined in a single leaseable coal unit since water quality deterioration will be assured. It is believed that at least a few places exist where essential functions of subirrigated alluvial valley floors can be recreated after mining. A subsequent section of this report suggests information requirements necessary to make pre-mining evaluations of such impacts.

Illustrations of Alluvial Valley Floors

Photographs are provided on the following pages to assist the reader in identifying alluvial valley floor areas. The photographs are representative of alluvial valley floors in Montana, Wyoming, and Colorado. Plates 1 and 2 were taken in spring and fall of 1976 along the East Fork of Armells Creek. Plate 1 is a view toward the southwest across the East Fork near County Highway 315. The channel is marked by the bushes in the center background of the photograph. The foreground is covered principally with grasses and big sage. The alluvial valley floor area is about 200 meters wide at this point and is mapped as including the subirrigated area within the lower terrace which is barely visible in the center of the photograph (see arrow). Plate 2 was taken about five kilometers west of Colstrip from the north side of the East Fork valley. The stream channel area is barely visible where subirrigated brush shows in the left center of the photograph (see arrow). A short distance upstream of this point the alluvial valley floor ends. The stream channel is deeply incised at this location, and the valley floor is a narrow flood plain not more than 100 meters wide. The upland valley is bordered by clinker outcrops associated with the Rosebud coal seam.

Plate 3 is a view of the Yellowstone River near Fallon, Montana. Drainages of this magnitude are characterized by wide flood plains, and the alluvial valley floor may extend up into the higher terraces. Though not examined in the field, it is likely that the lower terrace in the distant center of the photograph (see arrow) is an alluvial valley floor. The boundary of the alluvial valley floor along the near side of the valley appears to coincide with the dirt road in the foreground.

Plate 4 shows the Tongue River in the vicinity of Birney Day School, Montana. The arrows show the general extent of the alluvial valley floor. Here the alluvial valley floor is relatively broad and appears to be within the flood prone area (areas which have a one in 100 chance on the average of being inundated during any year). The foreground in Plate 4 is near the coal outcrop and, at this point, the surface mineable coal does not underlie the Tongue River (Malde and Boyles, 1976).

In the vicinity of the area shown in Plates 5 and 6, the coal does extend under the alluvial valley floor of the Tongue River. This area is upstream of that shown in Plate 4. Plate 5 is a view of the Tongue River looking south-southwest. The southern edge of the alluvial valley floor borders the low hills to the south (see arrow). Plate 5 shows this broad, irrigated field in November 1976. Plate 6 was taken earlier in May 1976, looking southwest of the upstream portion of the Tongue River and shows the western boundaries of the alluvial valley floor (see arrow). The northern limit of the alluvial valley floor is evident along the dirt road in the foreground of Plate 6 (see arrow). This alluvial valley floor is cropped for hay and has a ditch irrigation system.

Plate 7 shows the Tongue River near Decker, Montana. The Tongue River Reservoir is visible on the left side of the photograph, while the channel of Spring Creek is located at the foot of the low hill extending into the flat area on the right. The loading silos of the Decker Mine are along the horizon and right of center. The lowland area here produces hay, and the vegetation shows healthy growth during the drier months. Prior to establishment of the reservoir, it is possible the subirrigated area was somewhat smaller. The principal alluvial valley floor in the area remains the relatively narrow valley of Spring Creek (see arrow). The remaining flat area requires additional investigation before it could be judged an alluvial valley floor.

Plates 8 and 9 are photographs taken in the fall of 1976 along the Spring Creek drainage basin, about eight kilometers west of the Tongue River. Plate 8 is a view of a wet area along the South Fork of Spring Creek where ground water appears to be discharged. No area of alluvial valley floor has been identified between this area and the lower portion of Spring Creek shown in Plate 7. This wet area occurs along about 200 meters of the stream channel. Plate 9 shows a small ephemeral tributary to the South Fork of Spring Creek. This is not mapped as an alluvial valley floor because of its narrowness, but denser vegetation shows evidence of some water

DRAFT

retention and protection in the small, entrenched drainage.

Plate 10 shows a small ephemeral drainage channel lying between Deer and Coal Creeks, northeast of Decker, Montana, and east of the Decker West mine. The rocky material surrounding the flume is principally of clinker (i.e., baked shale and fused coal ash), the principal surficial material at this location. The area shows relatively vigorous vegetative growth during the drier months and is classified as an alluvial valley floor up to the terrace partially visible between a group of people (see arrow). Plate 11 is taken nearby at Deer Creek, a large tributary of the Tongue River, which also contains an alluvial valley floor, northern limit of which is indicated by the arrow. The vegetation of this area is principally grasses and is heavily used by stock.

DRAFT

Plate 12 is a view of Little Youngs Creek, a tributary to the Tongue River in Wyoming near the Wyoming-Montana border. Here overburden stripping and storage has begun to encroach on the alluvial valley floor (see Table 2). The alluvial valley floor is about 100 meters wide in this area.

Plate 13 shows the Tongue River near Kleenburn, Wyoming, north of Sheridan. The terrace levels are evident along the distant side of the river. Coal and clinker outcrops rim the valley. The alluvial valley floor is fairly broad at this location (see arrows).

Plates 14, 15, and 16 provide views of some of the tributary streams in northwestern Wyoming. Plate 14 shows Little Rawhide Creek, a tributary to the Little Powder River north of Gillette, Wyoming. This area is within the alluvial valley floor which is approximately 50 meters wide at the location shown. The minor terraces in the alluvial valley floor area (see arrow) are included.

Plate 15 shows Caballo Creek, a tributary to the Belle Fourche River in northeastern Wyoming, an upstream view toward the northeast. The alluvial valley floor is approximately 200 meters wide along the original (natural) channel. The width varies with the entrance of tributaries. The water impoundment* is a result of the mining operation. Strippable coal extends under this valley. A number of terraces are evident in the background (see arrows) and delineate the alluvial valley floor.

Plate 16 was taken in the Little Thunder Basin area at the gauging station installed on Little Thunder Creek. This intermittent channel has not been mapped as an alluvial valley floor though certainly the impounded run-off water (perched on silt and/or bedrock) is of value to stock and wildlife.

Plates 17 and 18 were taken in northwestern Colorado. Plate 17 shows a reach of the Yampa River Sixteen Kilometers west of Craig, Colorado, where the alluvial valley floor is quite broad. The nearest coal mining activity is presently six kilometers east. While this particular area has not been thoroughly investigated, the alluvial valley appears to extend to the low bluffs in the middle of the photograph (see arrows). Plate 18 is a view along Fish Creek located southwest of Steamboat Springs, Colorado, where spoiled overburden has been placed in the drainage channel. The alluvial valley floor at this point was 150 meters wide. The original stream channel has been filled and the man-made channel along the left of the photograph was in the process of being moved farther to the right at the time of the photograph. A railroad embankment rims the right side of the alluvial valley floor (see arrow).

---

* Impoundments created by post-mining grading may be beneficial if the impoundment, and the impounded water are safe and suitable for their intended use. Unfortunately, the incorrect assumption is often made that all impoundments are good for the semi-arid West. High evaporation rates which concentrate salts in the impoundments and leaching of spoils will cause some impounded water to be unfit for continual use. Impoundments constructed upgradient of spoils and intercepting ground water have a much greater likelihood of containing water suitable for agricultural and wildlife uses than do surface water impoundments and other impoundments intercepting water that has passed through spoils.

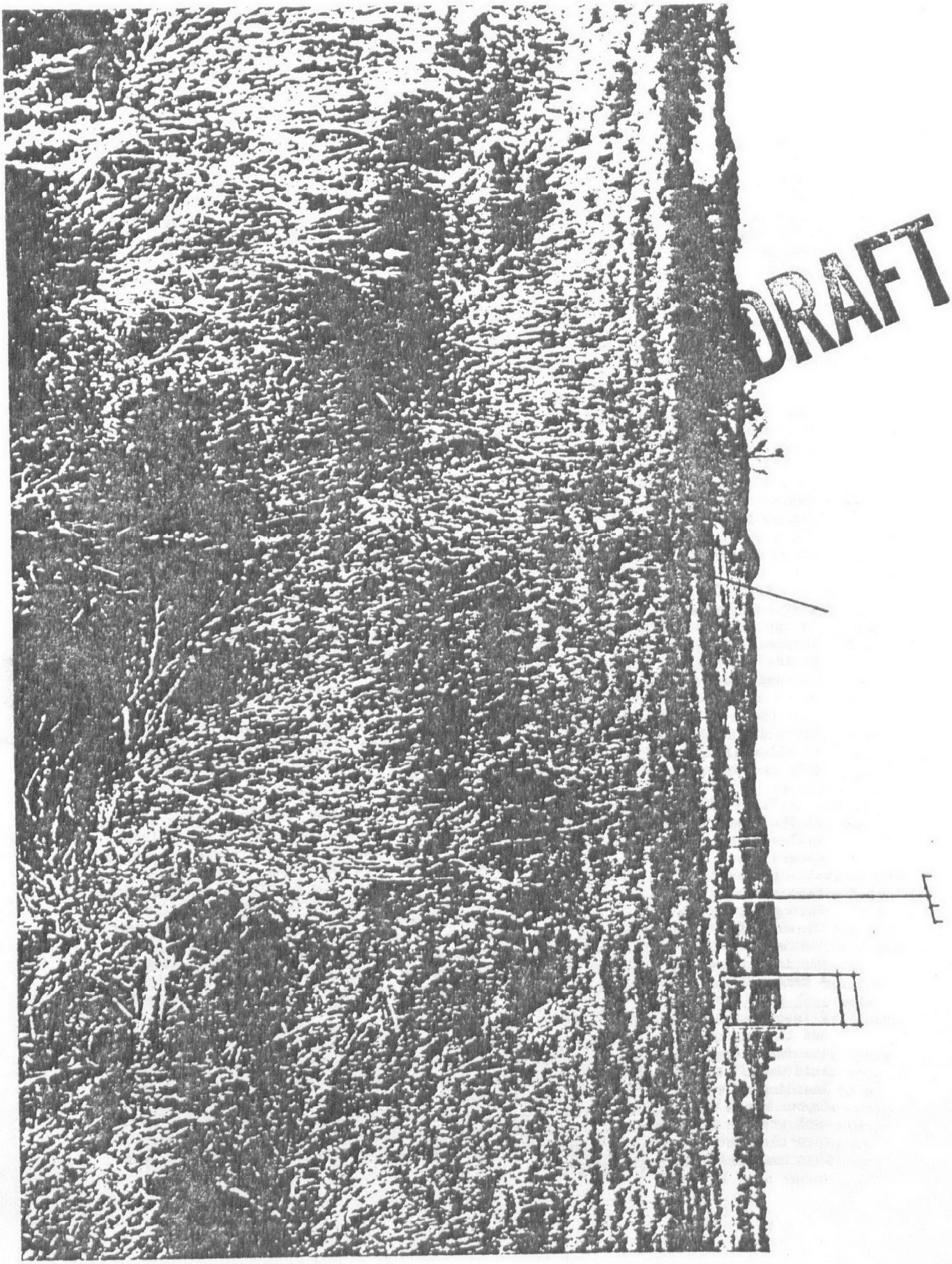

PLATE 1 - EAST FORK OF ARMELLS CREEK, NEAR COLSTRIP, MONTANA

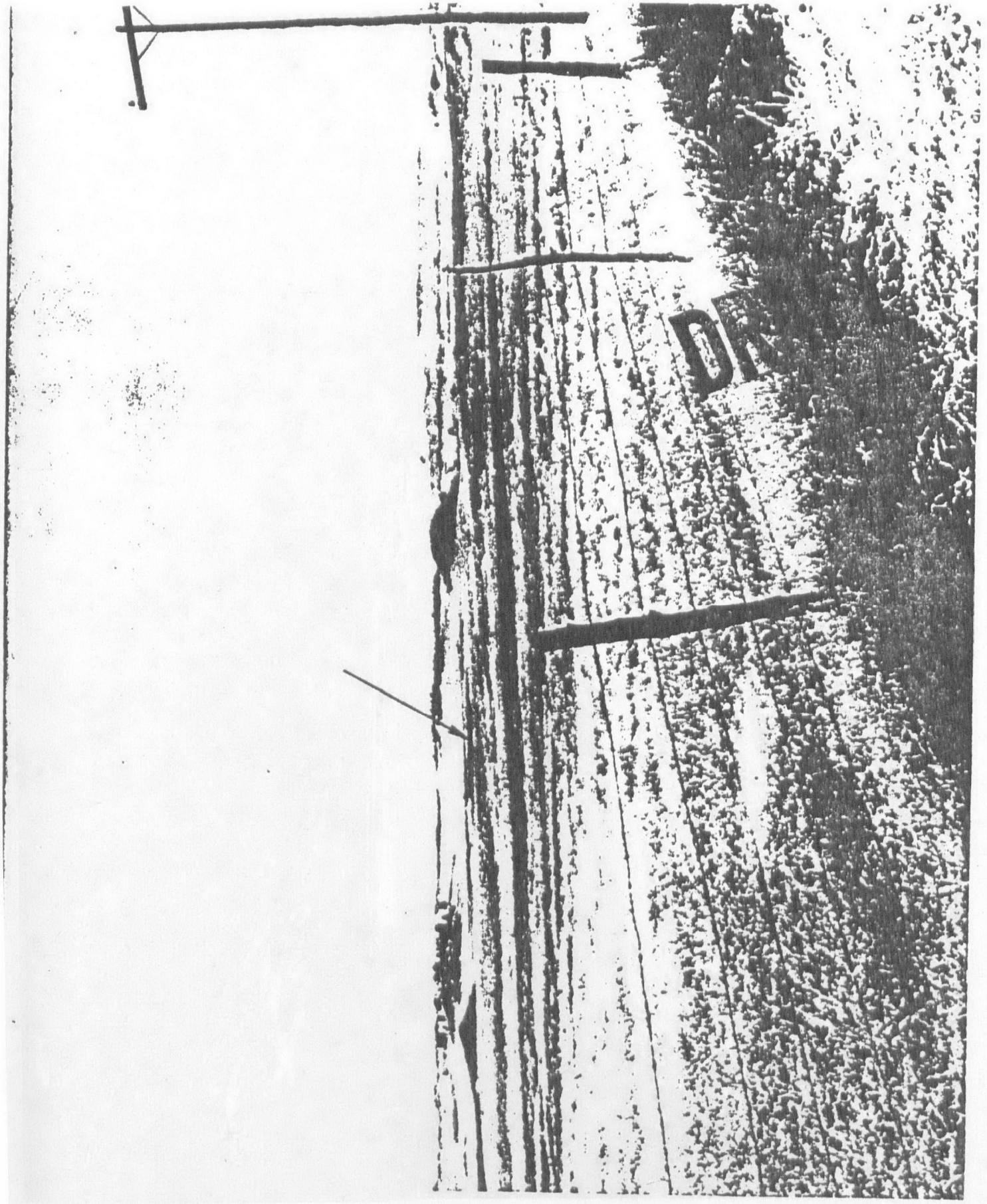

PLATE 2 - EAST FORK OF ARMELLS CREEK, WEST OF COLSTRIP, MONTANA

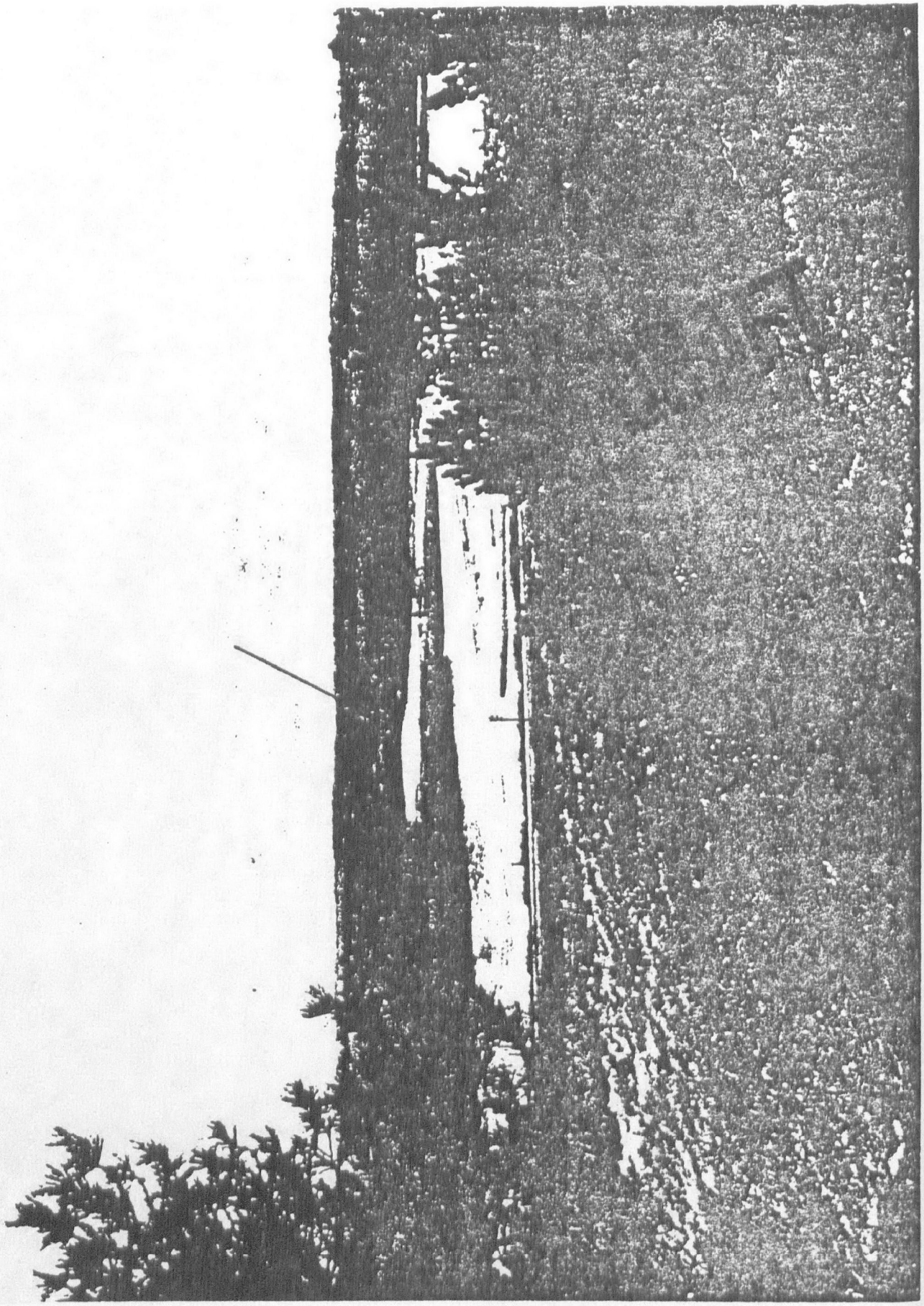

PLATE 3 - YELLOWSTONE RIVER IN VICINITY OF FALLON, MONTANA

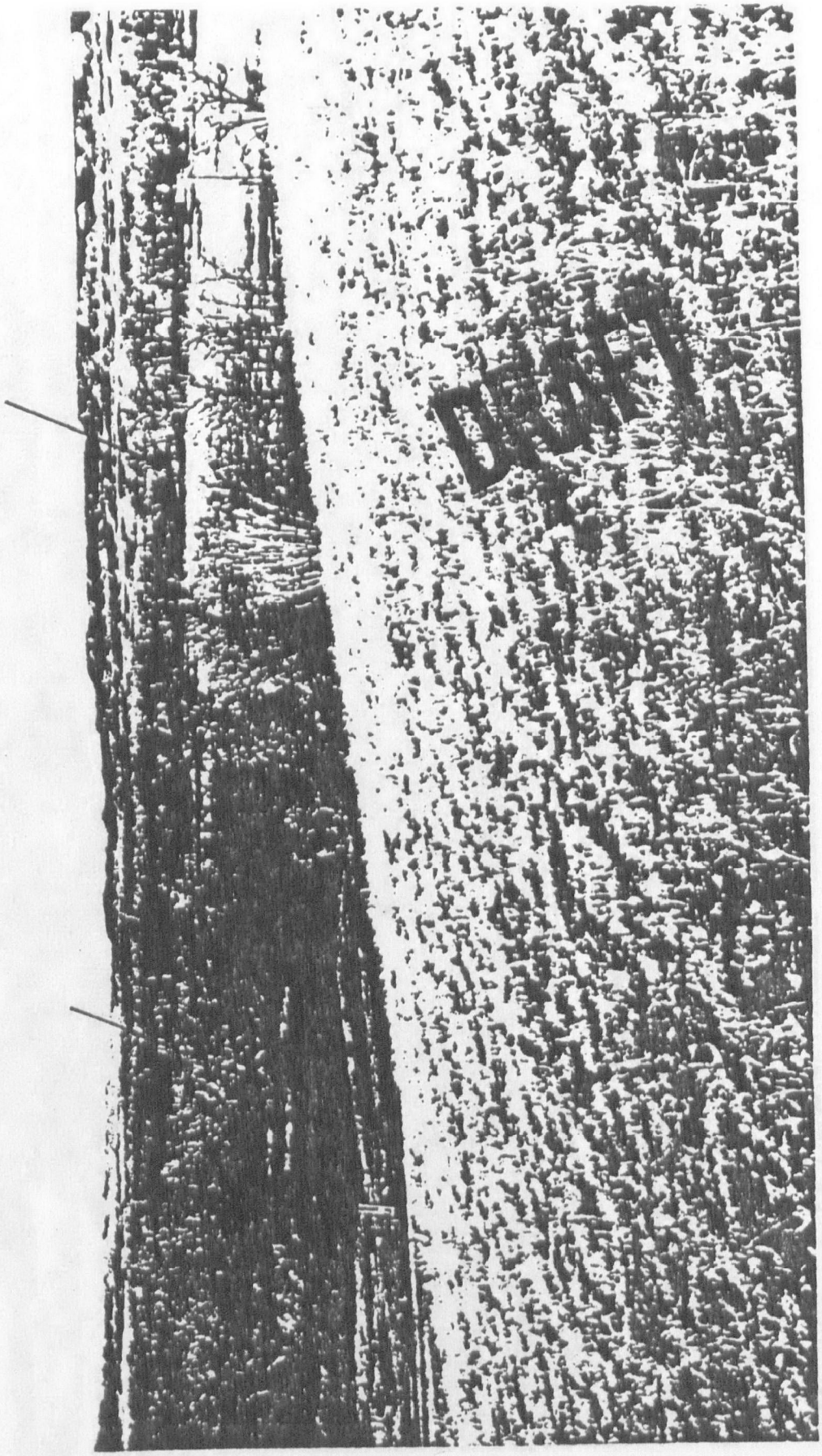

PLATE 4 - TONGUE RIVER AT BIRNEY DAY SCHOOL, MONTANA

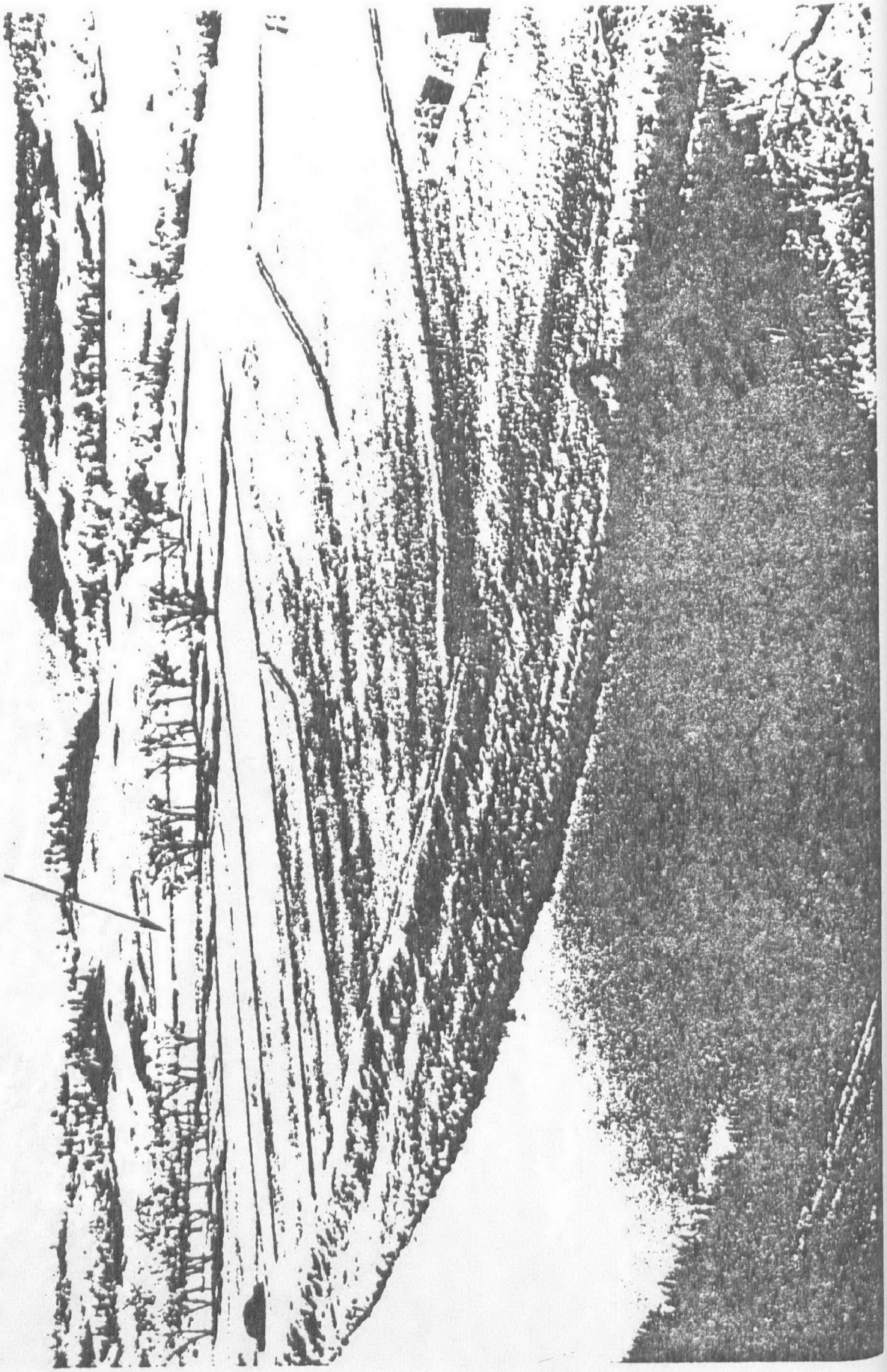

PLATE 5 - TONGUE RIVER NEAR CONFLUENCE WITH FOUR MILE CREEK

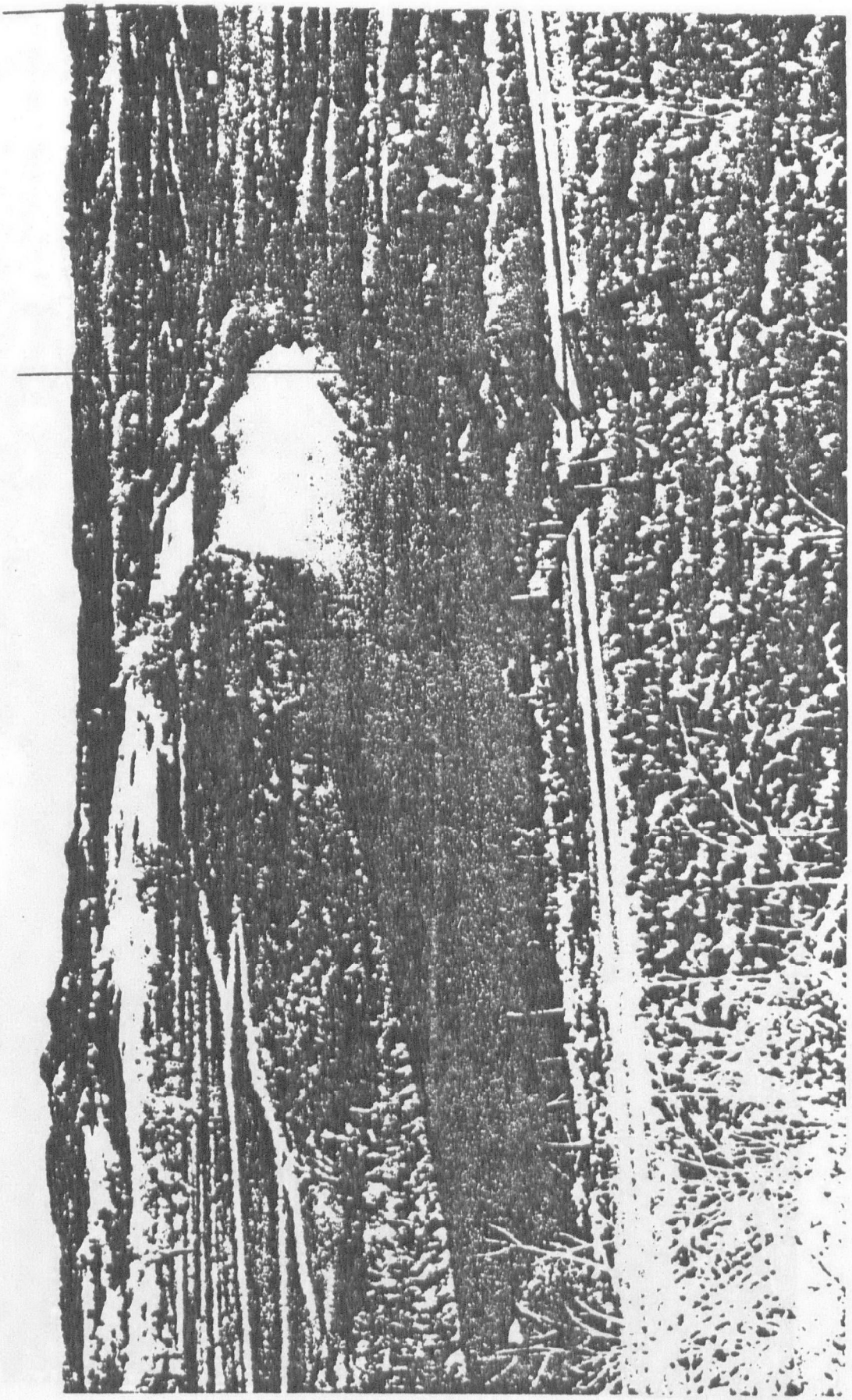

PLATE 6 - TONGUE RIVER NEAR CONFLUENCE WITH FOUR MILE CREEK

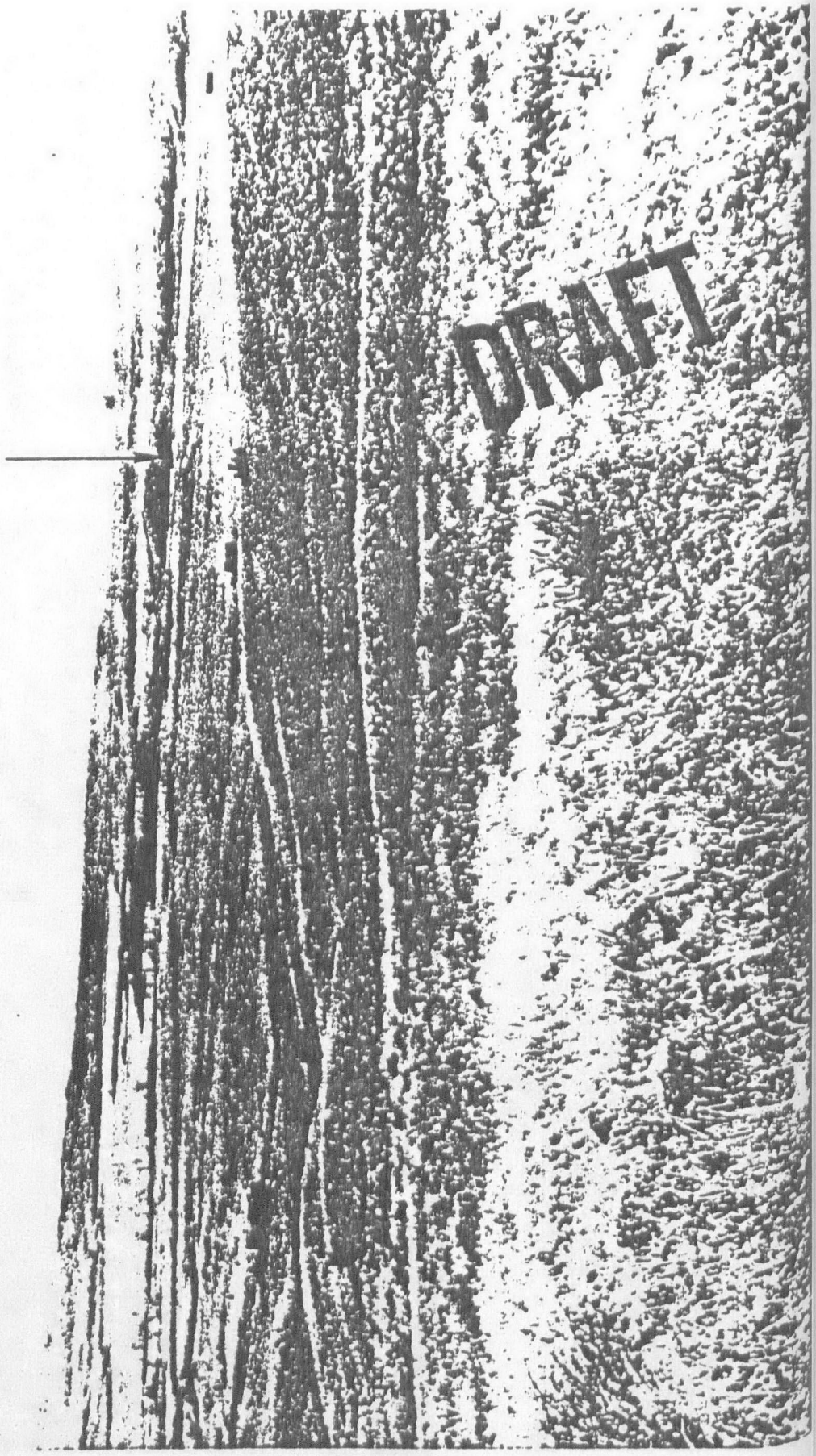

PLATE 7 - CONFLUENCE OF TONGUE RIVER AND SPRING CREEK

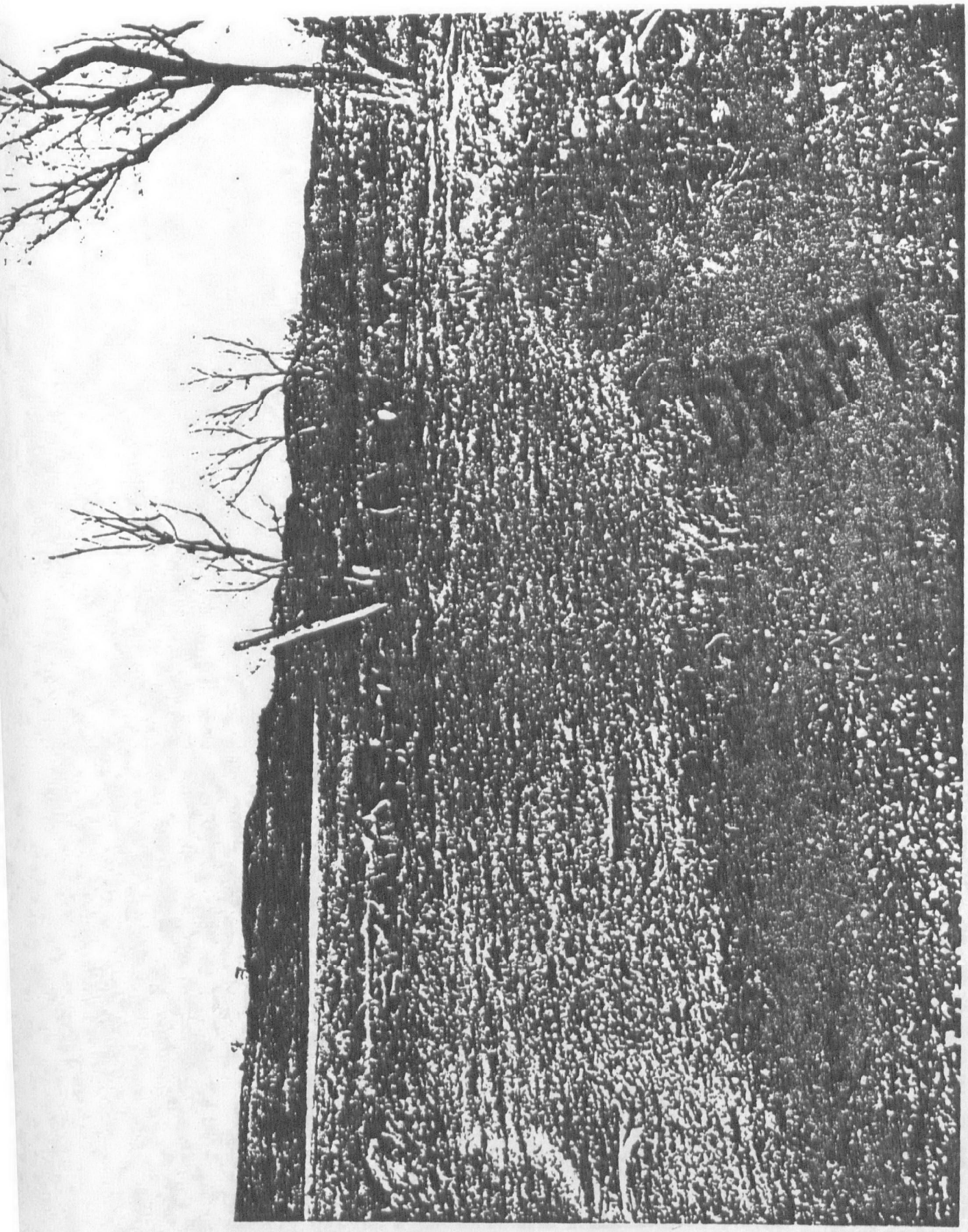

PLATE 8 - SOUTH FORK OF SPRING CREEK

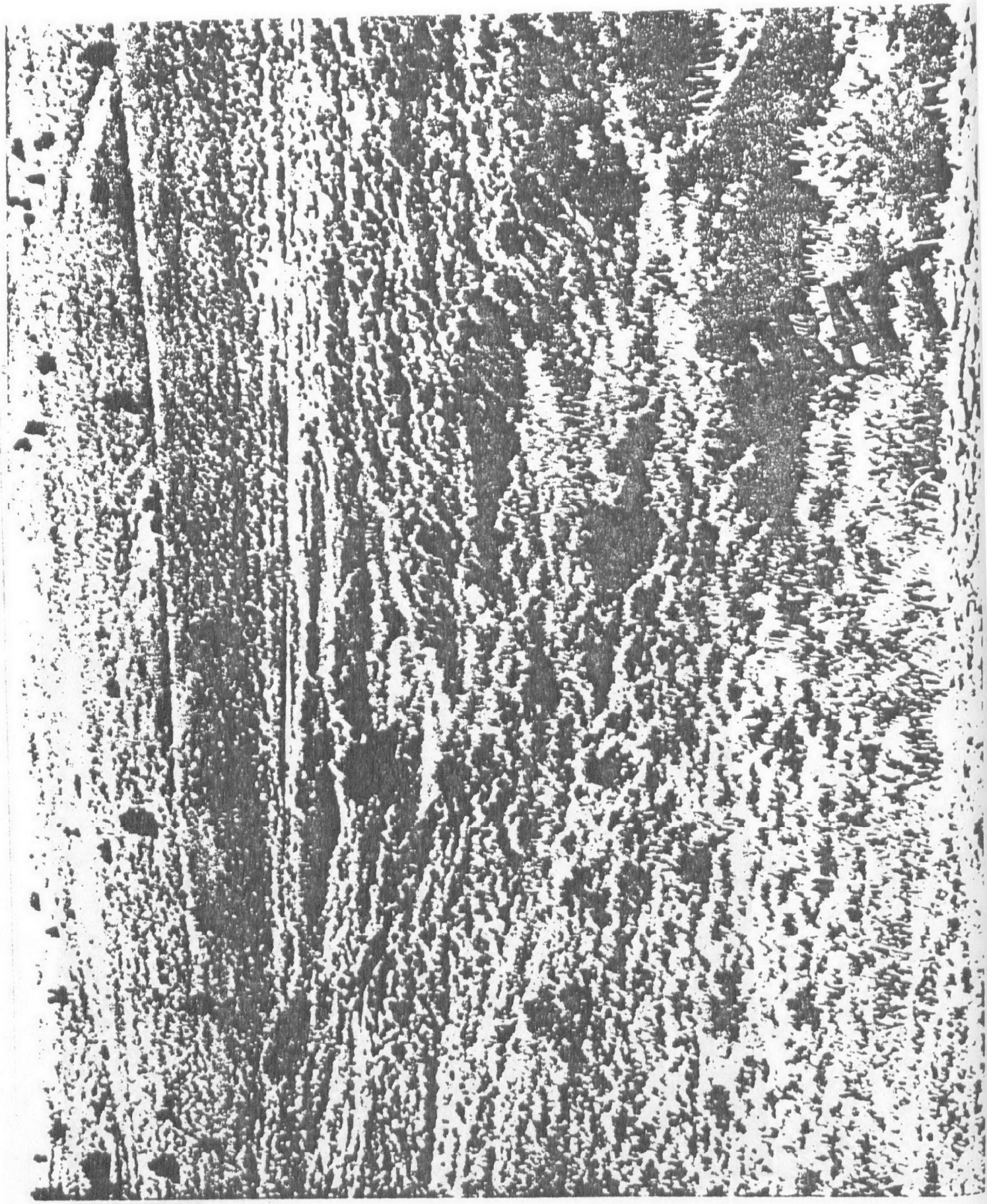

PLATE 9 - TRIBUTARY TO SPRING CREEK

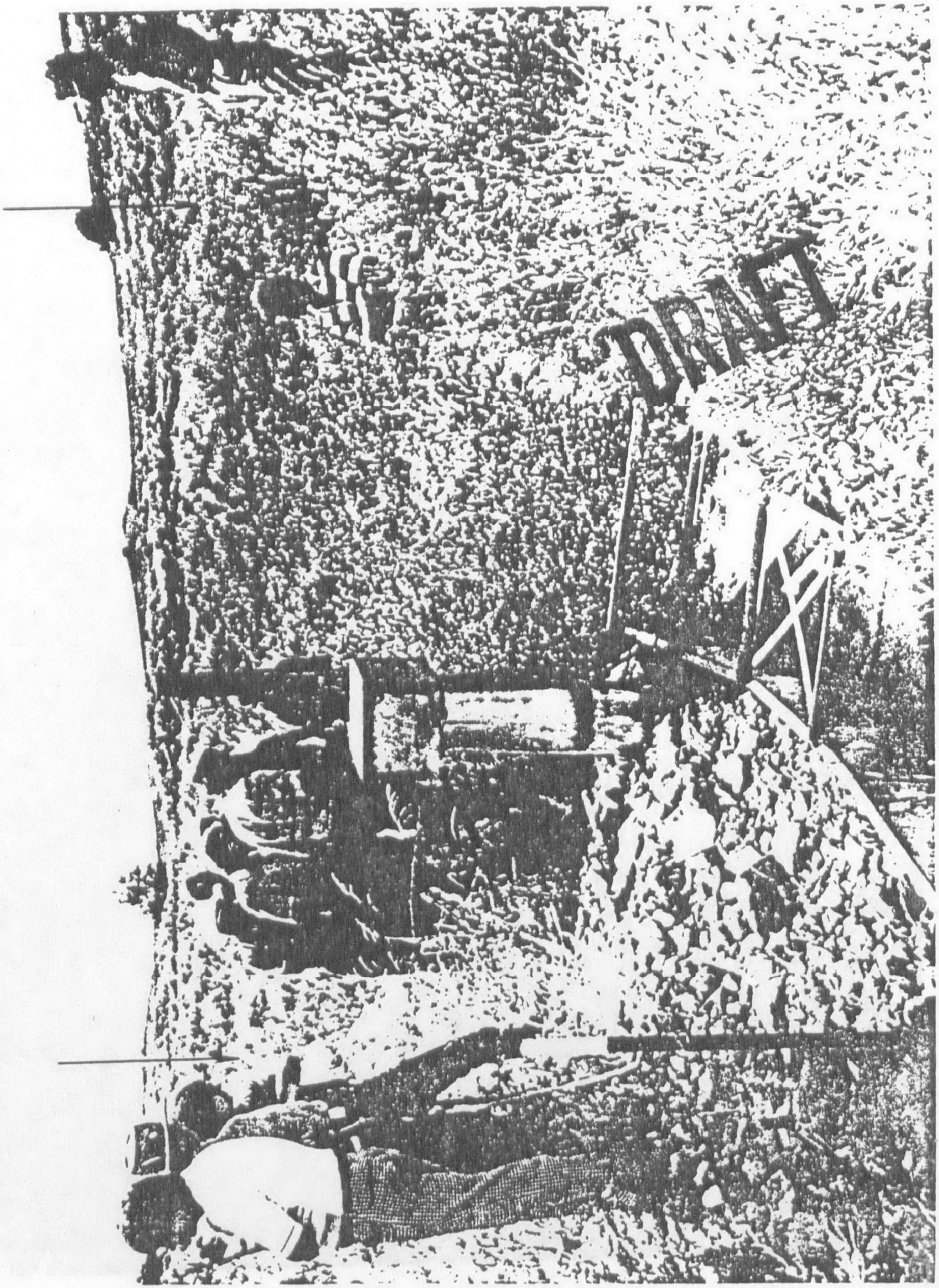

PLATE 10 - MINOR TRIBUTARY TO TONGUE RIVER

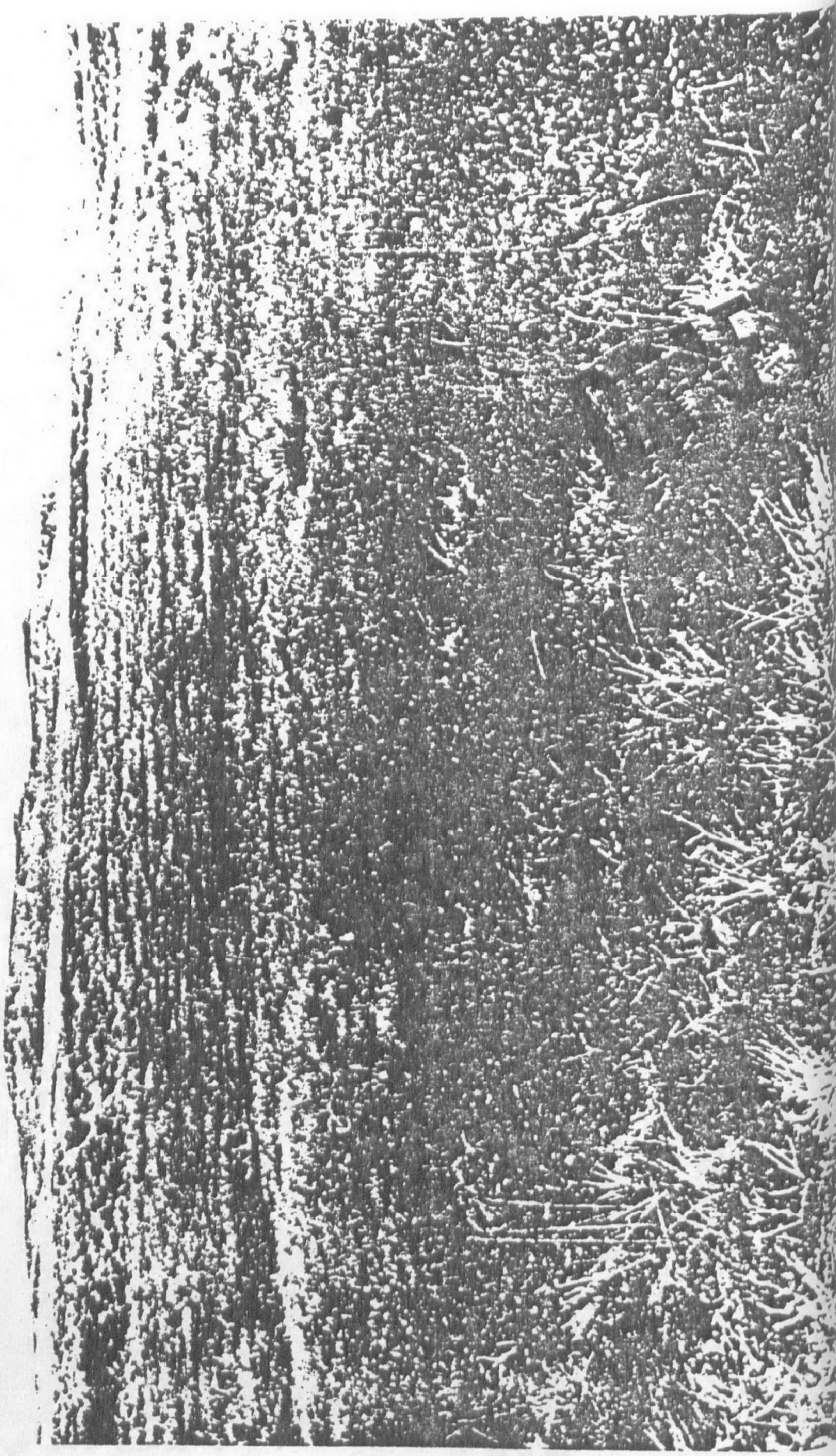

PLATE 11 - DEER CREEK EAST OF DECKER, MONTANA

PLATE 12 - LITTLE YOUNGS CREEK NORTH OF ACME, WYOMING

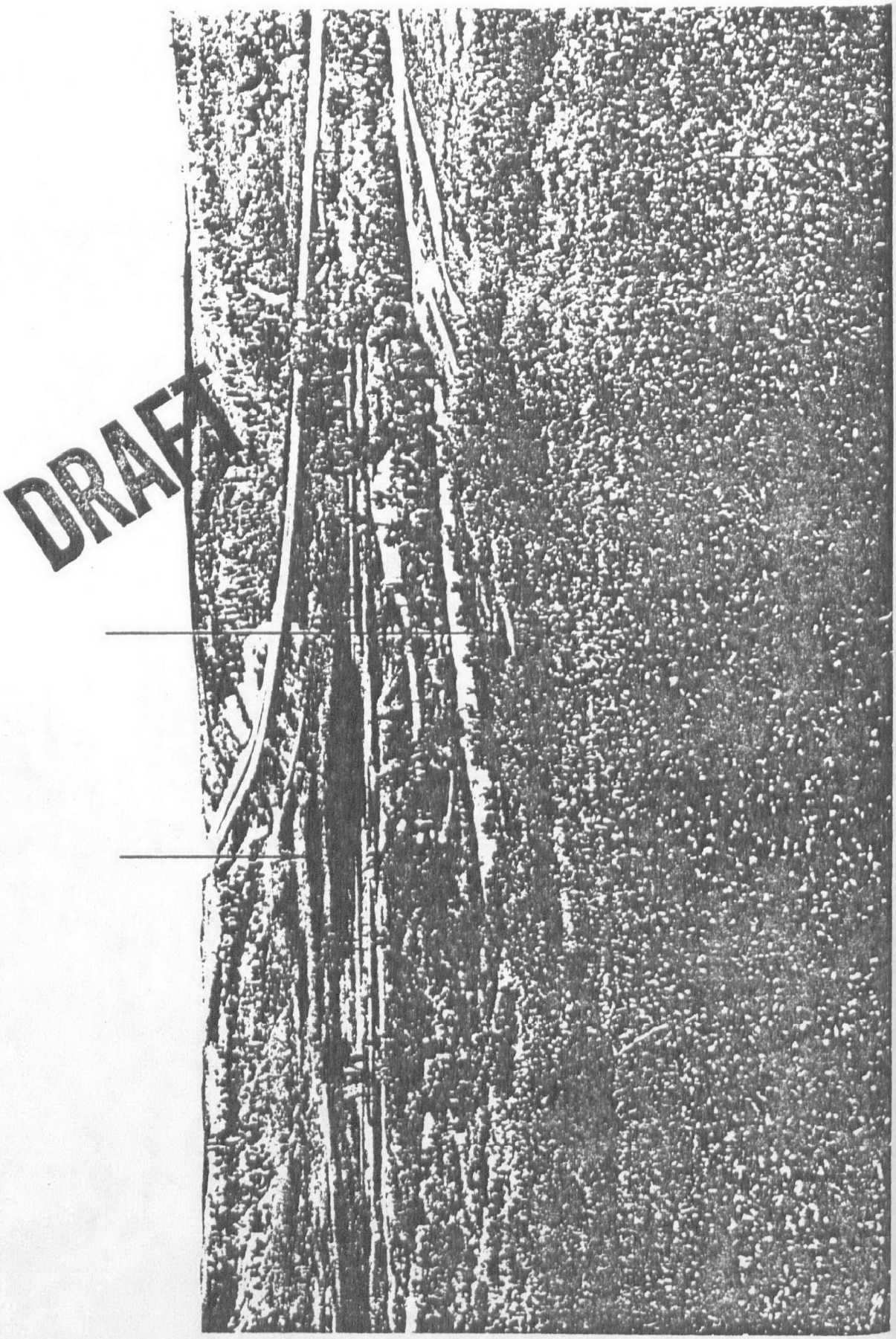

PLATE 13 - TONGUE RIVER NEAR ACME, WYOMING

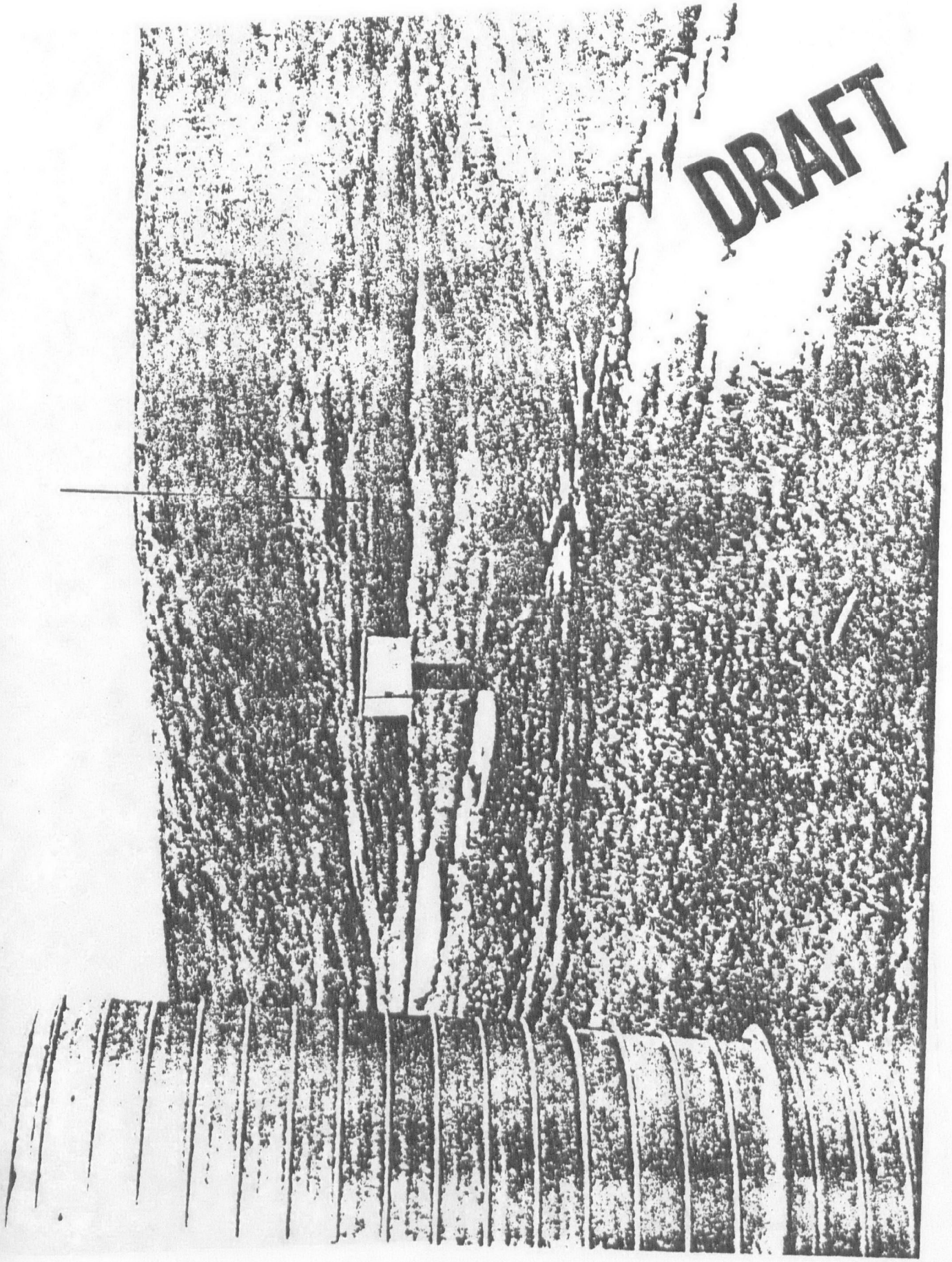

PLATE 14 - LITTLE RAW HIDE CREEK NORTH OF GILLETTE, WYOMING

PLATE 15 - CABALLO CREEK SOUTH OF GILLETTE, WYOMING

PLATE 16 - LITTLE THUNDER CREEK EAST OF RENO JUNCTION, WYOMING

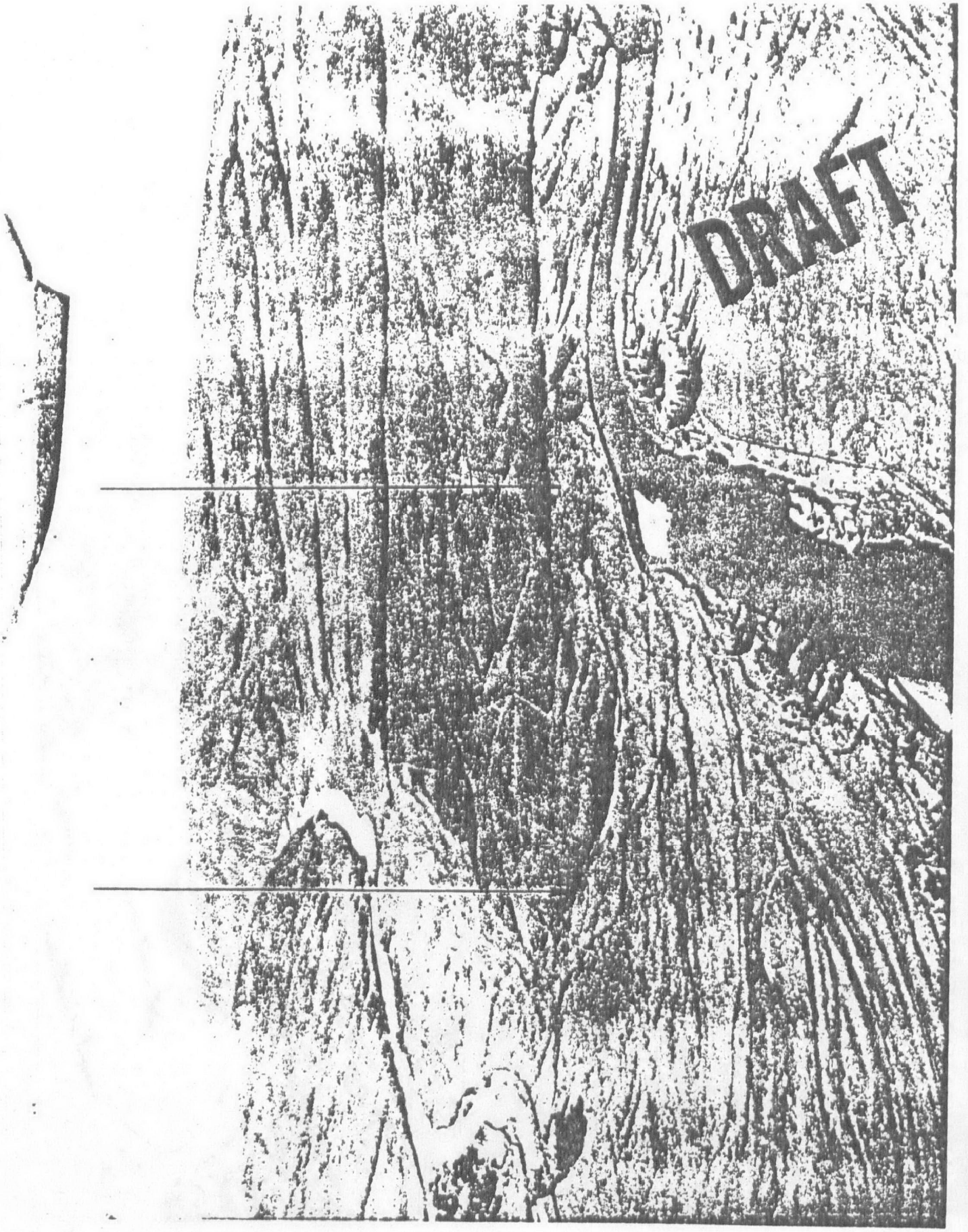

PLATE 17 - YAMPA RIVER WEST OF CRAIG, COLORADO

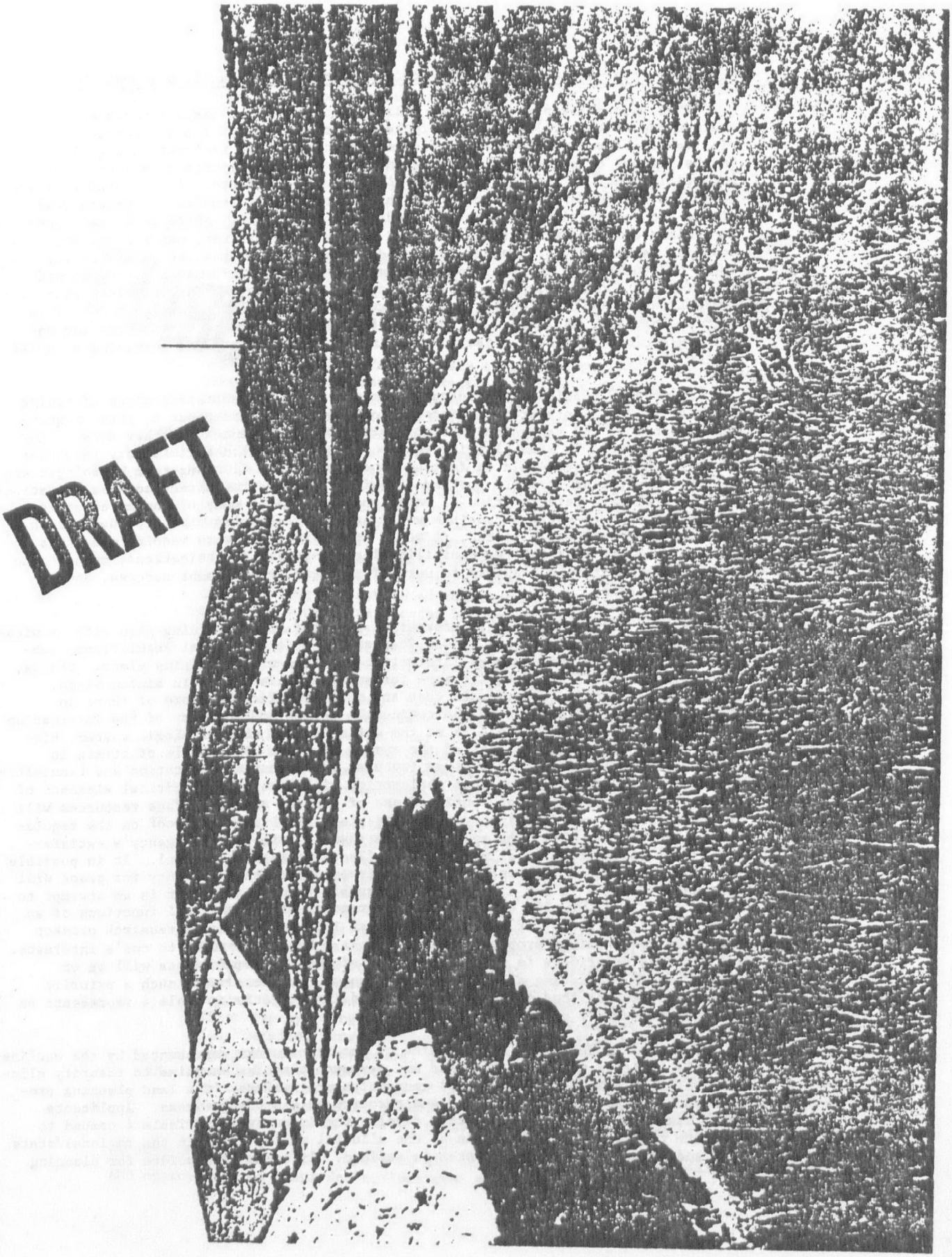

PLATE 18 - FISH CREEK SOUTH OF MILNER, COLORADO

Suggested Information Requirements for Applications to Mine Alluvial Valley Floors

This reconnaissance report was initiated to provide a basis for subsequent evaluations of the coal reserves affected by provisions for the protection of alluvial valley floors in proposed surface mining control and reclamation legislation. In the process of collecting information, it has been necessary to evaluate the potential impact of surface mining on alluvial valley floors. As the available information was compared with the known characteristics or results of surface coal mining and reclamation, information needs were identified. While it appears possible to reclaim certain hypothetical alluvial valley floor systems, natural systems have enormous variability. In order to provide a data base from which valid predictions as to the success of reclamation can be made, there are information requirements for the planning and pre-planning stages of a coal mine. In the case of mines which include alluvial valley floors, these information requirements are extensive. This section contains, as Table 4, a proposed list of requirements for information and for projections of future effects to be included in mining plans involving alluvial valley floors.

DRAFT

It appears possible to develop judgements as to the appropriateness of mining alluvial valley floors from the information submitted in response to these requirements (Table 4) and expansions thereof based upon experiences in other areas. Any approvals granted to mine alluvial valley floors based upon satisfactory responses to these requirements would be further conditioned upon (1) long-term hydrologic and biologic monitoring, and (2) posting of sufficient bond to correct adverse situations such as prolonged deterioration of water quality. Since many of the more complex ground and surface water situations would necessitate reclamation procedures that have not been thoroughly tested, it would appear reasonable to require operators and users of coal to bear the responsibility for pre-mining investigations, much of the post-mining monitoring required to warn of problems, to document success, and to correct failures.

Table 4 lists much of the information required for any mining plan with or without an alluvial valley floor. Under Chapter 30, Code of Federal Regulations, Subpart 211.10, there are numerous information requirements for mining plans. States, in varying degrees, have requirements for specific information in mining plans. Table 4 does contain requirements that are more specific than some of those in effect, especially in terms of indicating the detail and accuracy of the information supplied. Emphasis in Table 4 is on the definition of the hydrologic system, biologic interactions, the geology of the system in terms of the role of strata in other surface and subsurface systems (such as in supporting vegetation and transmitting water), in demonstrating that reclamation will reestablish critical elements of the natural system, and that continued use of surface and subsurface resources will be possible. It would be inappropriate to place the burden of proof on the regulatory agency. Therefore, the applicant must demonstrate (to the agency's satisfaction) that reclamation of alluvial valley floors will be successful. It is possible that with experience, the information requirements and the necessity for proof will decrease. Table 4 is not a list of all possible requirements, but is an attempt to obtain enough information to provide understanding of the critical functions of an alluvial valley floor. It may be argued that Table 4 outlines a research project since the requirements proposed therein can be debated according to one's interests, and that, as experience is gained, certain information requirements will be of little use in evaluating alluvial valley floors. However, until such a priority list can be established on the basis of field investigations, Table 4 represents an appropriate summary of requirements.

Prior to an applicant's submission of the information represented by the outline of Table 4, it is necessary for land and resource planning entities to identify alluvial valley floors using (at least) reconnaissance methods. The land planning process should also identify the land and resource values of the areas. Applicants for mining plan approvals can better develop the information in Table 4 needed to evaluate the plans after the role of the alluvial valley floor in the regional/state land and resource management system is defined. It seems appropriate for planning

entities to concurrently determine the role and long-term value of alluvial valley floors. Only in this manner could the impact of mining be completely evaluated.

TABLE 4

PROPOSED REQUIREMENTS FOR INFORMATION FOR COAL MINING PLANS INVOLVING ALLUVIAL VALLEY FLOORS (SURFACE OPERATIONS)

I. Geologic Information

IA. Regional Geologic Map of scale 1:250,000 showing formations and members, location of type sections and sources of information [illegible] within 25 kilometers of mine tract having ephemeral and [illegible] areas and 80 kilometers of perennial streams (where the stre[illegible] on the "area of operations" as defined in 30 CFR 211.2, C[illegible]deral Regulations).

IB. Regional structure Map of scale of 1:250,000 showing major fracture and fault systems in area covered by Regional Geologic Map (IA.), with measured attitudes (dip and strike) of major formations and the major geologic structures (may be included on Regional Geologic Map).

IC. Area of Operations Geologic, Topographic, and Structure Map of scale 1:24,000 (contour interval where required 3.3 meters or less) showing all strata of contrasting lithologies, attitudes, fracture patterns and faults located within the area of operations and/or with reference to type sections located outside the area. Map to be prepared from base data having a horizontal accuracy of ± 5 meters when denoting significant changes in bedrock lithology or structure.

ID. Affected Area Geologic and Structure Cross Sections of scale (vertical and horizontal 1:24,000 for affected area and 1:4800 for the area of operations showing all strata of contrasting lithologies and their attitude when such strata are located between the surface and within 70 meters below the deepest coal seam to be mined by surface methods or to a depth of 200 meters of the premining ground surface (within the area of operations) whichever most adequately represents the affected hydrologic system. Show locations of all points of detailed measurements. Locate cross sections on appropriate Geologic Maps. Provide at least two cross sections, one perpendicular to the general strike of strata within the affected area, one parallel to the strike, and any other cross sections deemed necessary to show departures from these sections (departures in terms of structure and lithology) where the departures affect the hydrology, overburden toxicity, or mining procedures. (Note: "Affected Area" defined in 30 CFR 211.2).

IE. Detailed Lithologic Logs of Cored Drill Holes located on transects across the subirrigated alluvial valley floor area(s) where such areas are located within the area of operations. Logs to show changes in lithology from the premining ground surface to a depth which includes 70 meters of the strata lying beneath the deepest coal seam proposed to be extracted. (Lithology based upon visual observations and any appropriate geophysical logs.) Provide at a scale of 1:200 in the vertical. These core holes will transect the alluvial valley floors and any related deposits as designated by the regulatory authority in sufficient number to provide the location to stratigraphic (lithologic) markers across the entire cross section (IF.) to within 2 meters and to show changes in strata that may affect the hydrology, overburden toxicity or mining procedures. (See also "Detailed Cross Sections of Alluvial Valley Floor Areas" (IF.) and requirements for hydrology data (III)).

IF. Detailed Cross Sections of Alluvial Valley Floor areas based upon the "Detailed Lithologic Logs of Cored Drill Holes" which show significant changes in subsurface lithology under the areas designated by the regulatory authority as alluvial valley floor areas (includes hydrologically-

1) "Regulatory Authority" refers to the public body with responsibility to review and approve mining plans for surface coal mines.

DRAFT

related alluvial deposits). The Cross Sections will generally be developed at two locations (longitudinally) along each alluvial valley floor area crossing the area of operations unless a lack of homogeniety requires the preparation of additional detailed cross sections along the longitudinal profile. All cross sections will be prepared at a vertical scale of 1:400 and at a converted horizontal scale and will show alluvial materials, lenses, weathered zones, and major fracture systems, in addition to the lithologic changes. An accuracy of ± 2 meters in the vertical data will be demonstrated by the applicant by use of statistical tests of field data.

IG. Detailed Chemical and Physical Information characterizing all overburden material scheduled to be disturbed in the area of operations. This information will be prepared and related to Cross Sections prepared for the affected area (ID.) and those prepared for the alluvial valley floor areas (IF.). Samples will be collected and analyzed to represent all strata of thickness exceeding 1 meter that are shown to be of significantly different chemical (or physical character 50% in quantitative analyses) unless directed by the regulatory authority to provide other information.

DRAFT

Parameter	Procedure
pH (determination on paste)	U.S.D.A. Handbook 60 "Diagnosis and Improvement of Saline and Alkali Soils", Page 102.
Conductivity mmhos/cm of saturation extract	U.S.D.A. Handbook 60, Pages 88 and 89.
Saturation percentage	U.S.D.A. Handbook 60, Page 84, Method 2 and 3a.
Calcium - Report on meq/L of the extract.	Preparation of extract U.S.D.A. Handbook 60, Page 84, Method 2 and 3a. By atomic absorption spectrophotometry (see Perkin-Elmer Analytical Methods).
Magnesium - Report in meq/L.	Same as for Calcium.
Sodium - Report in meq/L.	Same as for Calcium.
SAR (Sodium Absorption Ratio) calcium, magnesium and sodium from the above procedures 4, 5 and 6.	U.S.D.A. Handbook 60, Page 26, Calculation preferable. $Na^{+} + \sqrt{(CA^{++} + Mg^{++})/2} = SAR$ OR by nomogram procedure (20b), Page 102 and 103, U.S.D.A. Handbook 60.
Boron - Hot water extract reported as ppm.	U.S.D.A. Handbook 60, Page 142, Method 73b.
Particle size distribution (mechanical analysis). Report the percent of vfs (140-270) sieve size separately.	A.S.A. Agronomy Monograph No. 9, Method 43-5, Pages 562-566. If EC is 4 or more mmhos/cm include field texture determination.
Cadmium (ppm)	DTPA extractable. Soil Science Soc. of America Proceedings, Vol. 35. No. 4, 1971, P 600-602.

Copper (ppm)	DTPA extractable. Soil Science Soc. of America Proceedings, Vol. 35, No. 4, 1971, P 600-602.
Lead (ppm)	DTPA - same as copper.
Iron (ppm)	DTPA - 0.1N Ammonium nitrate or 0.1N Ammonium acetate or 0.005N nitric acid. Ref: Diagnostic criteria for plants and soils by Chapman.
Manganese (ppm)	DTPA extractable. Soil Science Soc. of America Proceedings Vol. 35, No. 4, 1971, P 6[illegible]
Zinc (ppm)	Same as Manganese.
Nickel (ppm)	Polarographic waves. ASA Agronomy Monograph No. 9, Pages 885-887, Method 56-6 or describe procedure.
Mercury (total ppb)	Acid soluble soil Hg by cold vapor using varian techtron. AA6 and varian Hg Kit. Ref: W.R. Hatch and W.L. Ott, Analytical Chemistry, Vol. 40, No. 14, December, 1968.
Selenium (ppm)	Analysis for the sum of selenate, selenite, and water soluble organic Se. Ref: ASA Agronomy Monograph No. 9, Page 1122, Method 80-3.2.
Molybdenum (ppm)	Acid Ammonium oxalate method 74-2, P 1054-1057. ASA Agronomy Monograph No. 9.
Boron (ppm)	Same as in Soil Survey A-8.
Nitrate (NO_3^-)	Same as in Retopsoiled layer B-1.
Ammonium (NH_4^+)	Same as in Retopsoiled layer B-1.

Type and percentage of clay. Physical and chemical properties as they may affect texture or chemistry of overburden, stability of material and hydrology of overburden.

Physical data reported are to include:

1. Bulk density of undisturbed overburden.

2. "Bulk density" of sample approximating physical state after mining ("post mining state"). See also Section VI.

3. Particle size distribution of "post mining state" of overburden materials. See also Section VI.

4. Particle size distribution of overburden samples crushed to state which approximates maximum exposure (to leaching of elements) of mineralogical forms.

For the area of operations, such data will be collected on a maximum spacing of one hole per 16 hectares. Within the alluvial valley floor area and

within any area of overburden which may be deposited in the alluvial valley floor area the maximum spacing should be reduced to one core hole per 10 hectares unless the results of analysis from the 16-hectare spacing demonstrate, to the satisfaction of the regulatory authority, that no additional variations in chemical or physical properties of overburden materials would be found using a denser core hole network in the alluvial valley floor.

II. Soils Information

IIA. Area of Operations Soils Map by soil series and phases scale 1:[illegible]000 clearly showing all soil mapping unit boundaries to a horizontal accuracy of ± 10 meters. Areas of highly contrasting soils that are 1 hectare or larger in size and areas of low contrasting soils that are 2 hectares or larger in size are to be delineated. The map will be accompanied by a description of each soil series, any soil associations, soil complexes, and each mapping unit, the latter described in terms of the dominant slope and range, typical parent material, typical depths and range thereof, kinds of soils and the percent of each kind of soil in mapping unit and the degree of consistency of the soil association over the area of operations. Show locations of samples. Describe erodability of soils and soil associations in their undisturbed and disturbed states as observed and/or calculated. Erodability must include that of the disturbed state.

IIB. Detailed Soils For Alluvial Valley Floor Area, scale 1:400, clearly showing all soil mapping unit boundaries to a horizontal accuracy of ± 2 meters with areas of minor or included highly contrasting soils that are 0.5 hectares or larger in size and areas of low contrasting soils that are 1 hectare or larger in size delineated. A description in detail similar to that required for the "Area of Operations Soils Map (IIA.)" will accompany this more detailed map(s). (The Alluvial Valley Floor Areas will be designated by the regulatory authority.)

IIC. Chemical and Physical Information Describing Soil Profiles in Area of Operations Present in tabular and narrated forms based upon analysis of soil profiles to a depth of 2.0 meters in the area of operations and to a depth of 4.0 meters within areas of alluvial valley floors, or to indicated bedrock if this occurs at shallower depths. Samples are to be collected at a minimum of two locations for each soil phase. Underlying soft, loamy, silty, or sandy strata are to be sampled to a depth of 30 cm below the weathered soil material. After the profile has been exposed and described, collect representative (and continuous) four-liter samples from each specific genetic horizon (top to bottom horizon) except the surface 15 cm. The surface layer is to be sampled from 0 to 15 cm. Genetic horizons of less than 8 cm in thickness need not be sampled. Genetic horizons or layers greater than 60 cm shall be divided into equal parts so that no sample (of four liters) represents a soil layer of greater than 60 cm. Each sample will be analyzed as follows - unless the regulatory authority determines, based upon preliminary data, that the number of samples analyzed can be reduced:

Parameter	Procedure
pH (determination on paste)	U.S.D.A. Handbook 60 "Diagnosis and Improvement of Saline and Alkali Soils", Page 102.
Conductivity - mmhos/cm of saturation extract.	U.S.D.A. Handbook 60, Pages 88 and 89.
Saturation percentage	U.S.D.A. Handbook 60, Page 84, Method 2 and 3a.

Parameter	Procedure
Calcium - Report on meq/L of the extract.	Preparation of extract U.S.D.A. Handbook 60, Page 84, Method 2 and 3a. By atomic absorption spectrophotometry (see Perkin-Elmer Analytical Methods).
Magnesium - Report in meq/L.	Same as for Calcium.
Sodium - Report in meq/L.	Same as for Calcium.
SAR (Sodium Adsorption Ratio) calcium, magnesium and sodium from the above procedures 4, 5, and 6	U.S.D.A. Hand[illegible], Calculati[illegible] $Na \div \sqrt{(Ca^{+}[illegible]/2} = SAR$ OR by nomogram procedure (20 b), Pages 102 and 103, U.S.D.A. Handbook 60.
Boron - Hot water extract reported as ppm.	U.S.D.A. Handbook 60, Page 142, Method 73b.
Particle size distribution (mechanical analysis) Report the percent of vfs (140-270) sieve size separately.	A.S.A. Agronomy Monograph No. 9, Method 43-5, Page 562-566. If EC is 4 or more mmhos/cm include field texture determination.
Trace mineral analysis as directed by the regulatory authority.	
Clay content.	
Change in physical characteristics as a result of removal and redeposition.	

DRAFT

IID. Continuous Soil Temperature Data recorded in lowland and highland areas and on differing aspects of slopes representative of the area of operations. These data should be collected for at least one year to show seasonal changes. Temperatures are to be regularly collected.

IIE. Calculations of Soil Loss of soils within the area of operations in their observed state and in various states of disturbance expected during mining operations. The "constants" assumed for each soil association will be stated and the sources of information will be shown.

III. Hydrologic Information

IIIA. Regional Hydrologic Map of scale 1:250,000 showing all surface drainage channels, major points of water diversions, zones of recharge to the ground water systems and significant areas of ground water discharge within the surface drainage watersheds covering the geographical area within 80 km of the area proposed for operations. Overlay with, or prepare separately, contour maps of ground water table of piezometric surfaces of water in each significant aquifer to be disturbed by mining using contour intervals of no more than 15 m and showing all data points.

IIIB. Detailed Hydrologic Map of the Area of Operations, scale 1:24,000, including the ground water basin(s) that supply ground water to the area of operations (including any alluvial valley floor area). Show all stream channels, recharge and discharge areas, all outcrops and subcrops of shallow aquifers in a form compatible with the "Area of

Operations Geologic and Structure Map" (IC.). Provide a base and contour map of water tables or piezometric surfaces of water in each significant aquifer to be disturbed by mining (including any aquifer lying less than 70 m below the deepest coal seam to be mined) and the highest undisturbed aquifer in the area of operations; perched water table conditions where observed, will be indicated. Contour intervals will not exceed 2 m except in special instances of steep ground water gradients, and should be presented with an accuracy of 15 percent. Flow lines shall be in indicated. (Preparation of this map will require the drilling of observation wells, or piezometer nests cased to ensure reception of water from only one aquifer during testing and sampling. Geologic data should be obtained when the wells are drilled: see "Geologic Information".)

IIIC. Detailed Information describing the characteristics of the shallow aquifers shall be obtained from aquifer pumping tests performed in at least two separate locations in each aquifer located within the area of operations. Data submitted will include field measurements of permeability, transmissivity and the storage coefficients. Core samples will be used to obtain laboratory estimates of pre- and post-mining permeabilities. Construction details of all wells used in preparing the information will be supplied. Pumping tests conducted in the areas designated by the regulatory authority as alluvial valley floor areas shall be designed to identify leakage between alluvial aquifers and deeper aquifers to be disturbed by mining (as well as leakage between multiple aquifers that may be disturbed). Locations of recharge to any alluvial valley floors will be identified and their role in the recharge cycle will be identified. All information will be reviewed and approved (as to its accuracy and interpretation) by a second independent and qualified party.

IIID. Water Quality Analyses of ground water samples collected (at least twice and not closer together in time than four months), from all wells used in preparing the "Detailed Hydrologic Map of the Area of Operations" shall be submitted. Timing of sample collection will, at a minimum, coincide with seasonal highs and lows in water table or piezometric surfaces. Samples shall represent as closely as possible aquifer water and shall not be contaminated by the well casing, cement, or drilling fluids. Analyses may be reduced if sufficient information is submitted to the regulatory authority to permit affirmation of consistency of water quality. Water Quality Analyses will include:

Parameter	Procedure
pH	Field meter
specific conductance (mmho/cm at 25 C)	Wheatstone bridge
turbidity (Jackson units)	Turbidimeter
total alkalinity as CaCO (mg/1)	Titration; electrometric; manual or automated method--methyl orange
total acidity (mg/1)	Electrometric end point or phenolphthalein end point
oil and grease (mg/1)	Liquid-Liquid extraction with trichlorotrifluoroethane
carbonate (mg/1)(meq/1)	Titration, electrometric; manual or automated method--methyl orange
bicarbonate (mg/1)meq/1)	Titration; electromatic; manual or automated method--methyl orange

Parameter	Procedure
chloride (mg/l)(meq/l)	Silver nitrate; mercuric nitrate; automated colorimetric-ferricyanide.
sulfate (mg/l)(meq/l)	Gravimetric; turbidimetric; automated colorimetric-barium chloranilate
calcium (mg/l)(meq/l)	EDTA titration; atomic absorption
magnesium (mg/l)(meq/l)	Atomic absorption; gravimetric
sodium (mg/l)(meq/l)	Flame photometric; atomic absorption
potassium (mg/l)(meq/l)	Atomic absorption; colorimetric; flame photometric
fluoride (mg/l)(meq/l)	Distillation--SPADNS
nitrate plus nitrate as N (total)	Automated (cadmium reduction); automated (hydrazine reduction)
orthophosphate as P (total)	Direct single reagent; automated single reagent or stannous chloride.
aluminum (Al) (Mg/l)	Atomic absorption
cadmium (Cd)	Atomic absorption
chromium (Cr)	Atomic absorption
copper (Cu)	Atomic absorption
iron (Fe)	Atomic absorption
lead (Pb)	Atomic absorption
manganese (Mn)	Atomic absorption
selenium (Se)	Atomic absorption
vanadium (V)	Atomic absorption
zinc (Zn)	Atomic absorption
Sodium Adsorption Ratio will be calculated	

DRAFT

Variations in water quality analyses collected on one day at the two locations in an aquifer greater than 25 percent will require that additional samples be collected and analyzed and, possibly that additional drill holes be installed and sampled to provide adequate information to explain the variations.

IIIE. An Inventory of all Existing Wells and Springs within 8 km of the area of operations shall be prepared in tabular form and locations shown on a map with a scale of 1:24,000. The following information shall be included: location, indicated condition of well (casing, completion, observed situations that could explain unusual data), surface owner, water use, land surface elevation, well depth, aquifer(s), depth to static water level, method of water production, water level during pumping, discharge and any existing water quality data (and source of water quality data).

IIIF. Surface Drainage Hydrology Information shall be submitted in tabular, graphic and narrative formats providing flow data (duration, low flow, flood frequency analyses) for USGS stations located nearest the proposed mine, estimates of recurrence floods (up to a minimum of 100-year recurrence intervals) for flow in each stream physically disturbed by mining and for streams presently receiving discharge from the disturbed areas, identification of all surface water diversions and impoundments for a distance of 35 km downstream of the area of operations, and providing longitudinal profiles of all streams to be physically reconstructed after mining (or significantly disturbed so as to change the gradient at a scale of 1:4800 with no vertical exaggeration. In streams or in tributaries to alluvial valley floors, the sediment loads shall be determined and the stability of the channels shall be evaluated. Channel roughness factors and channel durability shall be determined. The accompanying discussion shall describe channel armor (e.g. [illegible]) and sources of armor.

IIIG. Continuous Discharge Measurements shall be made in drainages involving tributaries to areas designated as alluvial valley floors located both within and downstream of the area of operations. Crest gages shall be established to assist in definition of areas affected by flood flows. Sufficient measurements to develop a water flow balance for the alluvial valley floor area will be collected. Stage-discharge correlations will be made for representative channels.

IIIH. Infiltration measurements will be conducted within all areas designated as alluvial valley floor areas to provide data for all soil associations within these areas. Runoff data will also be collected to provide estimates of the fate of precipitation in the alluvial valley floors, in areas of related alluvial deposits, and in areas of recharge related to the alluvial valley floors. If necessary to obtain representative data for disturbed materials, precipitation events may be simulated. This infiltration data will be plotted on soils maps (IIA. and IIB.).

III I. Water Quality Analyses data for flowing surface water courses taken during high and low conditions on perennial streams, and during representative flow events in any intermittent or ephemeral streams where such streams flow through or are tributary to alluvial valley floors. The data reported shall include results of analyses similar to those required for ground water samples (see IIID.) with suspended sediment added and metals determined in both the dissolved and suspended states.

IIIJ. Definition of the size and internal characteristics of any zone of capillary water existing beneath an area designated as an alluvial valley floor area and a description of the total unsaturated zone in terms of the rate of percolation of water, mechanisms holding water, saturation capacity and cause of permeability.

IIIK. Continuous Water Level Measurements will be collected at selected wells completed in aquifers located beneath, subcropping, or outcropping in alluvial valley floors. Water level measurements will be provided for all other wells at the time of sampling for water quality determinations. Seasonal fluctuations in water levels will be shown for cross sections of alluvial valley floors at a scale compatible with detailed geologic cross sections of alluvial valley floors.

IIIL. Precipitation and other climatological data collected "continuously" from a minimum of two locations for precipitation and evaporation (at least two aspects) and one location for other parameters in the affected area and presented to distinguish between intense, erosive rains, cumulative rainfall, seasonal and diurnal temperature changes (freeze and thaw cycles) over at least one year and which accurately characterizes the available moisture during the growing season.

IV. <u>Biologic Information (Vegetation)</u>

IVA. Vegetation Inventory maps of Affected Area, scale 1:24,000, showing

associations or communities based upon two or more dominant species accompanied by narrative describing species, successional stage, capabilities of land, growth rates or productivity, and current uses of vegetation (used for grazing, wildlife, crops).

IVB. Vegetation Inventory map of Areas Designated as Alluvial Valley Floors, scale 1:4800 showing plant varieties and communities accompanied by a narrative which includes: a complete listing of species, percent canopy coverage for each species, bare ground and litter, number of trees per acre for each species; a measure of production (production above ground at peak of growing season for (1) perennial, and (2) desirable annual species, animal units months (AUMS) the type is supporting, ground cover density and the potential AUMS under beneficial management); [illegible] representative cross-sections transecting the alluvial valley floor areas showing communities encountered at selected locations along the topography of the alluvial valley floor area. The vegetation survey shall be correlated with the soils survey and hydrologic investigation [illegible] observed relationships shall be explained. The inventory will establish the characteristic root systems of vegetation located within the alluvial valley floor area and will relate the root system as well as other growth factors to the relative productivity of hay, forage, and other species providing production to domesticated and wild animals. The condition and trend of species will be identified and analyzed to determine reasons for trends.

IVC. Current Use of Lands Within Alluvial Valley Floor Areas will be presented on 1:4800 scale map with the use categories including, but not limited to managed grazing, hay cutting, wildlife habitat, crop land, irrigated land, unimproved rangeland and marsh habitat. An accompanying narrative will quantitatively assess the economic importance of each land use to the affected area and to the county area(s) involved. Land uses over the previous ten years will be identified and assessed. The importance of subirrigation will be assessed and production changes as a result of changes in the ground and/or surface water system and the soil moisture content will be determined.

V. Biologic Information (Wildlife)

VA. Wildlife Inventory Map of Affected area showing habitat for major wildlife and ecologically important species, scale 1:24,000. Accompanied by a listing of wildlife species utilizing the area, seasons of use and degrees of dependence, including fawning or calving areas, nesting areas, strutting and dancing grounds, areas of critical cover, watering or feeding, and principal migration routes. Areas of critical winter habitat will be carefully identified, both as to their location and conditions making them critical.

VI. Projected "Operational" Information

VIA. Illustrated narrative of mining and reclamation procedures describing disposition of spoiled overburden, method of placement of overburden, sequence of placement of overburden to distinguish between differing lithologies, methods of compaction, soil replacement methods and source of soil, soil amendments proposed, revegetation methods proposed, post-mining maintenance and monitoring scheduled, and detailed experiences giving confidence of success for proposed reclamation procedures including pertinent measurements of post-mining conditions. This information shall be in sufficient detail to satisfy the regulatory authority that the critical functions of alluvial valley floors will be adequately restored.

VIB. Estimates of character and quality of spoiled overburden as porous materials in terms of porosity, storage coefficients, permeability, chemical stability (leaching, ion exchange capacity) and nutrient content (for vegetation) for a period of ten years after mining and

reclamation, or until equilibrium conditions are approached - based upon experience, and laboratory simulations of post-mining (and reclamation) conditions.

VIC. Post-reclamation Topographic Map of Area Operations showing all drainage courses, scale 1:4800, and showing expected changes as a result of material compaction.

VID. Post-reclamation longitudinal profiles along all reconstructed drainage channels, including the stream upstream and downstream; scale 1:400 for profiles of disturbed streams, scale 1:4800 for entire length of stream affected by disturbance (for a distance of not less than 5 km upstream and downstream of area of operations or to headwaters, whichever is the lesser upstream distance) with latitudinal cross sections (perpendicular to the drainage channel) for all reconstructed alluvial valley floors at 100 m intervals and for all major tributaries thereto showing channel form, methods of creating channel stability, expected flood plains for floods with recurrence intervals up to 100 years, methods of channel armor (e.g., clay, gravel) and post-mining sources of channel armor.

VIE. Illustrated narrative of post-mining subsurface hydrologic system expected in areas designated as alluvial valley floor areas. Show all recreated aquifers, expected locations of piezometric surfaces of confined aquifers, and water levels expected over local layers of less permeable strata (perched water tables) if any. Describe fluctuation in water table and recreation of subirrigation conditions. Provide comparisons between pre-mining and projected post-mining vegetative systems with estimates of levels of production of forage, ground cover density, species composition, and description of expected root systems in terms of depth and structure. Wherever possible utilize quantitative flow and chemical quality simulation models to project post-mining situation.

VIF. Estimation of Ground Water Recharge and Discharge Characteristics after mining in relation to areas designated as alluvial valley floor areas within and downstream of the area of operations. Identification of difficulties of reestablishing pre-mining ground water system (flow, quality, and depth to water). Identification of effects of coal mining in areas adjacent to the proposed area of operations.

VIG. Plans for post-mining monitoring of hydrologic and biologic systems of alluvial valley floors.

DRAFT

Summary and Conclusions

Reconnaissance mapping of subirrigated alluvial valley floors was conducted to determine how much land might be involved if special legislation evolved to protect areas of agricultural importance, and, indirectly, how much coal might be affected if mining of alluvial valley floors was determined to be environmentally unacceptable. This reconnaissance effort defines the limits of subirrigated alluvial valley floors adequately enough to serve as a basis for making first estimates of surface mineable coal that may be affected if the alluvial valley floors cannot be mined. A reconnaissance study does not provide sufficient information to estimate how much of the coal that lies outside the alluvial valley floor might be affected. That analysis appears possible only with additional experience in mines located at alluvial locations, including those outside alluvial valley floors, or with detailed mapping information that accurately describes the alluvial valley floor situation, the coal resource, and the effect of the reclamation procedures proposed. This analysis does confirm the suggestions of others that about three percent of the strippable coal resources of the western United States underlies subirrigated alluvial valley floors. The impact of alluvial valley floor protection requirements on the amount of surface mineable coal available may be expected to be about 10% if reclamation is not possible. In the judgement of the authors, only where there is a considerable density of alluvial valley floors is it likely that mining plans cannot be developed to exclude mining of such areas. It is likely that the critical functions of some alluvial valley floors can be reestablished except where complex surface and ground water systems are present and when shallow ground water quality is severely degraded as it passes through spoils.

This reconnaissance identification of the topographic (with some regard for geomorphology) and vegetative characteristics of alluvial valley floors within lands leased for coal extraction by surface methods provides a basis for estimating that three percent of the leaseholds in the interior western United States are overlain by alluvial valley floors. These alluvial valley floor designations encompass a land unit with a geohydrologic and biologic interrelationship that may be critical to the viability of an agricultural economy. However, the economic importance of the alluvial valley floor has not been assessed.

Alluvial valley floors are quite common in the Montana, Wyoming, and Colorado areas of coal development, but are less common in the coal regions of North Dakota, southwestern Wyoming, Utah, New Mexico, and Arizona. "Less common" refers to the size and amount of land identified as alluvial valley floors. For example, the mines examined in Arizona included areas of alluvial valley floors, but the area involved was less than 0.5 percent of the land area examined. Identification of these alluvial valley floors was accomplished through the use of aerial imagery, topographic maps, previous studies, and knowledge gained from past site visits.

Though it has been found to be a unique circumstance when any existing western coal mine is located entirely within an alluvial valley floor, alluvial valley floors may be supported by a coal seam aquifer system* that extends out from the alluvial valley. Therefore, the effects of mining an area of recharge may extend to an alluvial valley floor. In this case, the amount of coal affected could easily be raised if reclamation were not possible (e.g., if shallow ground water quality were degraded so as to interfere with use in the alluvial valley). In alluvial valley floors containing relatively thick coals overlain by thin overburden as well as in areas where alluvial aquifers are in a sense "perched" over the aquifer surface mineable coal, all coal may have to be withheld at least until the details of the natural system and the proposed mining plan provide the necessary assurance that areas may be reclaimed, at least to pre-mining productivity (and land uses).

* A moderately fractured coal seam which, often in combination with sandy strata, transmits sufficient water to be classified as an aquifer.

It is possible that an alluvial valley floor may be restored if the plant-supporting functions are principally dependent on the homogeneous physical water-holding characteristics of the plant growth medium and where there is no hydrologic complexity. In this case, restoration of the plant growth medium appears feasible.* In some cases, alluvial ground waters may be "perched", and reclamation will require recreation of differing zones of permeabilities and complex aquifer systems.

It may be that some standard mining methods such as selective placement and compaction of overburden can approximately recreate strata with low permeabilities in reclaimed areas. Rahn (1976) has suggested (but not demonstrated) this with information gathered in Montana and Wyoming. It may be possible to utilize clinker to recreate permeability if spoils are otherwise impermeable. On the other hand, the importance of the capillary and unsaturated zone in sustaining vegetation on alluvial valley floors is not known. Until this role is defined and until it is determined whether the plant growth medium can be reestablished in a manner which continues to support the grasses at a level equal to or better than that existing prior to mining, and until low permeabilities are recreated, there is a degree of uncertainty that all alluvial valley floors can be restored after mining.

DRAFT

A major concern is the effect of mining on water quality in or near an alluvial valley floor. The most significant question is whether saturated spoil material will produce a higher dissolved solids concentration or a different mix of dissolved elements that would adversely affect irrigated vegetation. In either case, the detrimental effect may not be limited to the mine site, but could progress downstream and down-gradient. It does appear that the quality of ground water passing through spoils should improve with time (as minerals are leached). But the period of time may be long - possibly more than 600 years.

Also of concern is the fate of a stream channel reestablished across a mined area. Hadley and King (1977) have noted that individual stream channels present individual sets of functional processes that dictate sedimentation and erosion. In cases where it is not possible to reconstruct the original longitudinal profile of a stream, there are serious questions as to whether artificial erosion control structures will require long-term maintenance and whether streams can be "taught" to meander along a new channel and flood plain.

A great deal of research has been and is currently being conducted with respect to the environmental effects and the potential for reclamation of surface coal mining in the interior western United States. However, there has been only limited dissemination of research results to date. Hydrogeologic investigations conducted near Decker and near Colstrip, Montana, are exceptions. The results of these site-specific investigations cannot yet be extrapolated to all other mines.

The lack of published data makes it impossible to report instances where alluvial valley floors were or are being mined with adverse long-term effects on the essential functions of these agriculturally important areas. Conversely, this lack of empirical data makes it difficult to demonstrate that the essential functions of alluvial valley floors can be restored after mining.

Site-specific investigations can more adequately define alluvial valley floors and are necessary to determine the "mineability" of a particular alluvial valley floor. Such investigations are particularly needed if one is to determine whether proposed coal extraction operations located near an alluvial valley floor will "adversely affect the quantity and quality of water in surface and underground systems that supply these valley floors..." (510)(b)(5)(B) proposed Federal Bill HR 2 (see Appendix 2). While it is likely that many surface mines will be located within a hydrologic flow system that ultimately reaches an alluvial valley floor, it is presently impossible to develop generalized statements as to when such mines may

* It is considered "feasible" to replace soils and suitable overburden and to fertilize and supplement natural soil moisture for a finite period.

adversely affect the waters of an alluvial valley floor. At this stage in our understanding of the hydrologic impacts of mining shallow coals in the West, there is dependence upon site-specific investigations, such as those at the Decker, Belle Ayr, Big Horn, Wyodak, Gascoyne, and Rosebud (MT) mines. It is hoped that some improved assessment of regional impacts on water quality as a result of increased coal mining will be developed in the near future.

In addition, much uncertainty remains regarding the role of the alluvial valley floor in the regional economic system. As yet, no land use and productivity analyses have adequately evaluated the alluvial valley floor's contribution to the agricultural and recreational economic sectors.

Since this analysis of subirrigated alluvial valley floors was precipitated by proposed legislation, it is appropriate to use the findings of this reconnaissance investigation to evaluate technical aspects of the proposed legislation. Lands, including alluvial valley floors, should be mined unless proper planning allows the essential functions can be restored. Such planning would be facilitated by the applicant's demonstration that the procedures proposed will adequately restore, or improve upon, those characteristics of the natural system that currently dictate existing environmental equilbrium.

Information in this paper suggests that selected areas of subirrigated alluvial valley floors could be mined and the long-term agricultural productivity reestablished in time. Thus, instead of addressing only a ban on mining in alluvial valley floors, this paper also reports on an alternative procedure - that of requiring an applicant to submit a detailed environmental analysis, the content of which is proposed. The detailed environmental analysis would involve extensive requirements for both baseline information and demonstration that proposed reclamation techniques are likely to be successful. There must be sufficient data to permit regulatory agencies to make the judgement that the essential functions of the alluvial valley floor will be successfully restored and/or protected. The reclamation methods proposed must have been demonstrated under similar circumstances. Though a ban would directly involve only three percent of the strippable coal reserves, it would probably make uneconomic the mining of an additional amount of coal due to the need to leave coal in place for pit wall stability and due to the difficulty in creating logical mining units.

Alluvial valley floors which have sufficient subirrigation to support agricultural use (harvesting of hay, for example) are, conceptually, important to the economy of the western United States. They must be protected. In view of the uncertainties caused by the few mining plans submitted to mine alluvial valley floors, it may be appropriate to temporarily defer surface mining of coal in subirrigated alluvial valley floors until a well-defined and comprehensive research program has provided additional information concerning the effects of mining under complex hydrologic conditions.

Acknowledgements

The authors are indebted to Dr. Harold E. Malde and Mr. Richard Keefer (USGS) who kindly made available the results of their field work and also Mr. Richard Hadley who made available his expertise in the area of hydrology and erosional stability of stream channels.

The efforts of an advisory group set up to assist with and review the findings are also appreciated. This group consisted of, in addition to Mr. Malde and Mr. Keefer, J. Herrmann (EPA), J. Mayberry (USGS), J. Ferry (EPA), R. Holmes (EPA), E. Arthur (EPA), and A. Lees (FEA).

There are, of course, differences of opinion between the authors and the advisory group, and the opinions offered in this report are those of the authors, and thus do not necessarily reflect the positions of members of the advisory group.

All aerial imagery was collected under the direction of the Remote Sensing Operations Branch, Remote Sensing Division, Environmental Monitoring and Support Laboratory of the U. S. Environmental Protection Agency. Most interpretations of the aerial imagery were performed by the Remote Sensing Laboratory of Lockheed Electronics Company, Inc., under EPA contract #68-03-2153. The financial and technical support thus provided by the Office of Research and Development of the U. S. Environmental Protection Agency is gratefully acknowledged.

References Cited

American Geologic Institute, 1972. Glossary of Geology. AGI, Washington, D.C.. G. R. McAfee, Jr. and C. L. Wolf (editors).

Hadley, R. F. and N. J. King, 1977. Alluvial Valley Floors and Surface Mining in the Western United States. Report in draft for review. U. S. Department of the Interior, Geological Survey, Denver, Colorado.

Heath, M. E., D. S. Metcalfe, and R. F. Barnes, 1973. Forages. Iowa State U. Press, Ames. 755 pp.

Malde, H. E. and J. M. Boyles, 1976. Maps of alluvial valley floors and strippable coal in forty-two 7½-minute quadrangles, Big Horn, Rosebud, and Powder River Counties, southeast Montana: USGS Open File Report 76-162.

McWhorter, D. B., J. W. Rowe, M. W. Van Liew, R. L. Chandler, R. K. Skogerboe, D. K. Sunada, G. V. Skogerboe, 1977. Surface and subsurface water quality hydrology in surface mined watersheds. U. S. EPA, Industrial Environmental Research Laboratory, Cincinnati.

National Academy of Sciences, 1974. Rehabilitation potential of Western Coal Lands -- A report to the Energy Policy Project of the Ford Foundation. Ballinger Publishing Company, Cambridge, Massachusetts. 198 pp.

Rahn, P.H., 1976. Potential of Coal Strip Mine Spoils as Aquifers in the Powder River Basin: Project Completion Report. Old West Regional Commission.

Rural Electrification Administration, 1974. Final Environmental Impact Statement.

Schmidt, J., 1977. Alluvial Valley Floors in East-central Montana and Their Relation to Strippable Coal Reserves; Reconnaissance Report. U. S. Environmental Protection Agency, Region VIII, in cooperation with State of Montana.

United States Department of Interior and State of Montana, Department of State Lands, 1976. Draft Environmental Impact Statement, Proposed Plan of Mining and Reclamation -- East Decker and North Extension Mines. Decker Coal Company, Big Horn County, Montana.

U. S. Geological Survey, 1974. Shallow Ground Water in Selected Areas in the Fort Union Coal Region. By the Ground Water Subgroup of Water Work Group, Northern Great Plains Resources Program. USGS Open File Report 74-48.

Van Voast, W.A., and R. B. Hedges, 1975. Hydrogeologic Aspects of Existing and Proposed Strip Coal Mines near Decker, southeastern Montana. Montana Bureau of Mines and Geology, Bulletin 97.

Van Voast, W. A., and R. B. Hedges, 1975. Hydrogeologic Conditions and Projections Related to Mining Near Colstrip, southeastern Montana. Montana Bureau of Mines and Geology, Billings, Montana.

Weaver, J. E., 1968. Prairie Plants and Their Environment. U. of Nebraska Press, Lincoln. 276 pp.

DRAFT

Appendix 1

	Mine	Operator	State (& County)	Legal Description
A-1	Black Mesa	Peabody Coal	Arizona (Navajo)	T34-36N, R13-16W
A-2	Kayenta	Peabody Coal	Arizona (Navajo)	T34-36N, R13-16W
C-1	Black Diamond Strip	Canon Coal Corp.	Colorado (Fremont)	T20S, R70W, 24
C-2	Canadian Strip	R. Flesch & Son, Inc.	Colorado (Jackson)	T8N, R78W,2
C-3	Corley Strip (S&A)	Canon Coal Co.	Colorado (Fremont)	T20S, R69W, 6,7,18,19,30,31
				T20S, R70W, 1,12,13,24
C-4	Craig	Utah International	Colorado (Moffat)	T6N, R90W, 29-32
				T5N, R90W, 5-8, 17, 18
				T6N, R91W, 11-16,21,23-29,33-36
				T5N, R91W, 1-5, 9-11
C-5	Denton Strip	Milner Coal Co.	Colorado (Routt)	T6N, R86W, 20-21
C-6	Edna Strip	Pittsburgh & Midway	Colorado (Routt)	T4N, R85W, 7,18,19
				T5N, R85W, 19,30,31
				T4N, R86W, 12-14,19,23-25
				T5N, R86W, 25,36
C-7	Energy Strip #1	Energy Fuels Corp.	Colorado (Routt)	T4N, R86W, 7,8,9,17,18,19,30
	Energy Strip #2			T4N, R87W, 11-14,23-25
	Energy Strip #3			T5N, R85W, 6,7,18,19,30,31
				T5N, R86W, 1,2,3,10-15,18-21,24,25 27-34
				T5N, R87W, 23-26,35,36
				T6N, R86W, 34-36
C-8	Grizzly Creek Strip	Sunflower Energy	Colorado (Jackson)	T7N, R80W, 32,39
				T6N, R80W, 4
C-9	Jewel Strip	Horner Coal Co.	Colorado (Las Animas)	T30S, R65W, 31
C-10	Marr Strip #1	Kerr Coal Co.	Colorado (Jackson)	T9N, R78W, 25,26,35
				T8N, R78W,2
C-11	Nucla Strip	Peabody Coal Co.	Colorado (Montrose)	T47N, R16W, [illegible]
C-12	Seneca Strip #2	Peabody Coal Co.	Colorado (Routt)	T5N, R87W, 1-[illegible]
				T6N, R87W, 2,[illegible],11,13,24-27,34-36
C-13	Williams Fork Strip	Empire Energy Corp.	Colorado (Moffat)	T5N, R91W, 6
				T6N, R91W, 29-32 ([illegible] areas)
C-14	_____	Moon Lake Electric	Colorado	T4N, R89W
C-15	Colowyo	W.R. Grace	Colorado	T3N, R93W, 2-4,8-11,14-[illegible]
				T4N, R93W, 27,28,33-[illegible]
M-1	Absaloka (Sarpy Creek)	Westmoreland Resources	Montana (Big Horn)	T1N, R37E, 23,25,26
M-2	Absaloka II	Westmoreland Resources	Montana (Big Horn)	T2N, R36E, 1-4,8-14,23-26
				T1N, R36E, 1-4,8-14,23-26
				T1N, R37E, 4-9,17-21,28-33

DRAFT

	Mine	Operator	State (& County)	Legal Description
M-3	Absaloka III	Westmoreland Resources	Montana (Big Horn)	T1S, R37E, 1,2
				T1S, R38E, 2-5,8-10
				T1N, R38E, 17-21,25,29-32
				T1N, R37E, 1-3,10-15,22-27,34-36
M-4	Big Sky	Peabody Coal Co.	Montana (Rosebud)	T1N, R41E, 13-15,21-23,26,27
M-5	Circle West	Burlington Northern	Montana (McCone)	T21N, R45E, 19,26-35
				T20N, R45E, 2-8,10-13,17,18
				T20N, R44E
				T20N, R46E
M-6	Coal Creek	J.H. Schoonover	Montana (Musselshell)	T8N, R25E, 16
M-7	Rosebud	Western Energy Co.	Montana (Big Horn)	T2N, R38E, 12,13,23-25
				T1N, R39E, 1-5
				T2N, R39E, 19,28,36
				T1N, R40E, 1-6,8-16
				T2N, R41E, 13-15,22-35
				T1N, R42E, 7,17,18
				T2N, R42E, 18-20,28-30,32
M-8	Decker East	Decker Coal Co.	Montana	T9S, R41E, 7,8,18
				T9S, R40E, 12-14
M-9	Decker North	Decker Coal Co.	Montana	T9S, R40E, 3,4,9,10
				T8S, R40E, 33,34
M-10	Decker #1 (West)	Decker Coal Co.	Montana (Big Horn)	T9S, R40E, 9,10,15-17,21,22
M-11	PM Strip	PM Coal Co.	Montana (Musselshell)	T6N, R26E, 23
M-12	East Sarpy Creek	AMAX Coal Corp.	Montana (Big Horn)	T2N, R37E, 1,2,11,12,23-27,35,36
				T1N, R37E, 1,12
				T1N, R38E, 5-7,8,17
				T2N, R38E, 5-8
M-13	Savage	Knife River Coal Co.	Montana (Richland)	T20N, R57E, 22,23,[illegible]-28
M-14	Spring Creek	Pacific Power & Light	Montana (Big Horn)	T8S, R39E, 1[illegible]36
				T8S, R40E, 30[illegible]
M-15	Storm King	Divide Coal Mining Co.	Montana (Musselshell)	T6N, R26E,23
M-16	Youngs Creek	Shell Oil	Montana (Big Horn)	T9S, R38E, 14-1[illegible]2T-23,26-28
				T8S, R38E
				T8S, R37E
NM-1	McKinley	Pittsburgh & Midway	New Mexico (McKinley)	T16N, R21N, 11-1[illegible]
				T17N, R20W, 31-34,36
				T16N, R20W, 2,4-8,[illegible],16-18, 21,22,26-28,31

DRAFT

	Mine	Operator	State (& County)	Legal Description
NM-2	Navajo	Utah International	New Mexico (San Juan)	T29N, R15W, 8-10,15-17,20-22,28-32 T28N, R15W, 7-9,16-21,28-32 T28N, R16W, 25,34-36 T27N, R15W, 31 T26N, R15W, 6,7,18,19 T27N, R16W, 1-3,10-12,14,15,22-27 34-36 T26N, R16W, 1-3,9-16,22-27,33-36 T25N, R16W, 1-5,8-17,20-24
NM-3	San Juan	Western Coal Co.	New Mexico (San Juan)	T30N, R15W, 2-4,9,10,15,16,21,22 27,28,33,34,20
NM-4	Star Lake	Peabody Coal Co.	New Mexico (McKinley)	T20N, R7W, 3,9-16,22-27,36 T20N, R6W, 16-22,26-36 T19N, R6W, 1-5,9-12 T19N, R7W, 6,7 T19N, R7W, 1
NM-5	Sundance	Amcoal, Inc.	New Mexico (McKinley)	T14N, R17W, 9
NM-6	West York Canyon Strip	Kaiser Steel	New Mexico (Colfax)	T30N, R19E, 2-4,9-11 T31N, R9E, 20-22,27-29,32-35
NM-7	Gamerco	Carbon Coal Co.	New Mexico (McKinley)	T16N, R9W, 33 T15N, R19W, 2-4,10-16,21,22
NM-8	_____	Mesa Resource Co.EPNG	New Mexico (San Juan)	T23N, R14W, 27-33 T24N, R15W, 24-26
ND-1	Beulah South (and North)	Knife River Coal	North Dakota (Mercer) (Oliver)	T143N, R87W, 6,7,8,18 T143N, R88w, 1,2,11-14 T144N, R87W, 8,9,16,17
ND-2	Center	Baukol-Noonan	North Dakota (Oliver)	T142N, R84W, 23-25,35,36 T142N, R83W, 21,30 T141N, R84W, 1
ND-3	Falkirk	North American Coal	North Dakota (McClean) (Washburn)	T146N, R82W, [illegible] except 21 T146N, R83W, [illegible],23-26,35-36 T146N, R81W, [illegible],30,31 T145N, R82W, [illegible] T145N, R83W, [illegible] T145N, R81W, 6
ND-4	Gascoyne	Knife River Coal Co.	North Dakota (Bowman)	T131N, R99W, 32-[illegible]29
ND-5	Glenharold	Consolidation Coal Co.	North Dakota (Oliver)	T144N, R84W, 3-5,8-10,[illegible],18-20 23,24,[illegible]32 T143N, R84W, 5,6

	Mine	Operator	State (& County)	Legal Description
ND-6	Husky Strip	Husky Industries	North Dakota (Stark)	T139N, R95W, 7,8,17
ND-7	Indian Head	North American Coal	North Dakota (Mercer)	T143N, R87W, 6,7
				T144N, R88W, 19,28-33
				T143N, R88W, 6
				T144N, R89W, 24-26,36
				T143N, R89W, 1
ND-8	Larson (Noonan)	Baukol-Noonan	North Dakota (Burke)	T162N, R94W, 3-5,8-11,14-16
ND-9	Nelson	GEO Resources	North Dakota (Williams)	T154N, R100W, 17
ND-10	Smith-Ulman	NL Industries	North Dakota (Adams)	T129N, R94W, 5-8
				T129N, R95W,1
ND-11	Sprecher	Sprecher Coal Co.	North Dakota (Grant)	T134N, R90W, 29
ND-12	Velva	Consolidations Coal Co.	North Dakota (Ward)	T152N, R81W, 28,34-36
				T151N, R81W, 1,2
U-1	Alton	Utah International and Nevada Electric	Utah	T40S, R5W, 4,5,7-9,17,19,29,13, 14,23-27,34
				T39S, R6W, 11-14,23-27,34,35
				T40S, R6W, 3-5,8-10
				T39S, R5W, 6,7,17-20,29-33
				T39S, R4W, 23-27,32-35
				T40S, R4W, 2-9,18,19
U-2	Emergy Strip	Consolidation Coal Co.	Utah (Emery)	T22S, R6E, 22,27,28,33,34
U-3	Mill Draw	Energy Plus, Inc.	Utah (Uintah)	T3S, R22E, 8
U-4		Peabody Coal Co.	Utah	
U-5		Resources Company	Utah	
WA-1	Carbon River	Donald Hume	Washington	
WA-2	Centralia	Washington Irrigation and Development	Washington (Lewis)	T15N, R1W, 28
WY-1	Eagle Butte	AMAX Coal Corp.	Wyoming (Campbell)	T51N, R72W, 16,21-23,26-28,34,35
WY-2	Belle Ayr	AMAX.	Wyoming (Campbell)	T47N, R71W, 3-5
				T48N, R71W, [illegible], 32-35
WY-3	Big Horn	Big Horn Coal Co.	Wyoming	T57N, R84W, [illegible],21-23,27
WY-4	Black Butte	Black Butte Coal Co.	Wyoming (Sweetwater)	T19N, R100W, [illegible],7,9-11,14-16
				[illegible],22,28,29,31,32
				T18N, R101W, [illegible]
WY-5	Black Thunder	ARCO	Wyoming (Campbell)	T42N, R70W, [illegible]
				T43N, R70W, [illegible],27-29,33-35
WY-6	Buckskin	Shell Oil	Wyoming (Campbell)	T52N, R72W, 32
				T51N, R72W, 5

	Mine	Operator	State (& County)	Legal Description
WY-7	Caballo	rater Oil	Wyoming(Campbell	T48N, R70W, 7,18,19 T48N, R71W, 11-16,21-24,26-28
WY-8	Coal Creek	Peabody Coal Co.	Wyoming	T43N, R70W, 3,4
WY-9	Cordero	Sunoco	Wyoming (Campbell)	T46N, R71W, 2,3, T47N, R71W, 13-15,22-24,26,27,34,35
WY-10	Dave Johnston	Pacific Power & Light	Wyoming (Converse)	T35N, R74W, 18,19 T36N, R74W, 2,6,7,10,11 T35N, R75W, 1-3,10-13,16,24,36 T36N, R75W, 1-3,10-12,14-16,21,22 27,28,33-36
WY-11	East Antelope	Best Coal Co.	Wyoming	T41N, R71W, 35
WY-12	East Gillette	Kerr-McGee	Wyoming (Campbell)	T50N, R71W, 5,6,8,9,20-22,27-29, 33,34
WY-13	Elkol	Kemmerer Coal Co.	Wyoming	T21N, R116W, 20
WY-14	FMC	FMC	Wyoming (Lincoln)	T20N, R117W, 11-14,22-24,26,27,28,34 T20N, R116W, 17-20,30 T19N, R117W, 4,10
WY-15	Jacobs Ranch	Kerr-McGee	Wyoming (Campbell)	T43N, R69W, 6,7 T43N, R70W, 1-3,10-15
WY-16	Grass Creek	Northwestern Resources	Wyoming (Hot Springs)	T46N, R99W, 26
WY-17	Jim Bridger	Bridger Coal Co.	Wyoming (Sweetwater)	T21N, R100W, 7,16-22,26-29,33-36 T20N, R100W, 2-5,8-15,22-27,35 T21N, R101W, 2,3,10-14
WY-18	Lake DeSmet	Texaco	Wyoming	T52N, R82W
WY-19	Medicine Bow	Arch Minerals	Wyoming (Carbon)	T23N, R83W, 5-9,17-20,29,31-34 T24N, R84W, 25 T24N, R84W, 28-33 T23N, R84W, 1,11-14,25,35
WY-20	Muddy Creed		Wyoming (Fremont)	T6N, R1E, 17,20
WY-21	North Rawhide	Crater Oil Co.	Wyoming (Campbell)	T52N, R72W, 31,33 T51N, R72W, 3-6,9-15,31, T50N, R71W, 7,18,19,30 T50N, R72W, 1,12,13,24
WY-22	P.S.O.#1	Public Service Co. of Oklahoma	Wyoming (Sheridan)	T58N, R84W, 22
WY-23	Rimrock	Energy Development	Wyoming	T22N, R82W, 2-10,14,15,18,20,22, 26,28,30,32,34 T23N, R82W, 32

DRAFT

	Mine	Operator	State (& County)	Legal Description
WY-24	Rochelle	Rochelle Coal Co.	Wyoming	T41N, R70W, 1-5,8-12,17 T41N, R69W, 6,7,18 T42N, R69W, 31
WY-25	Rosebud	Rosebud Coal Co.	Wyoming (Carbon)	T22N, R81W, 2,3,10,11 T23N, R80W, 21,28,29,31,32 T23N, R81W, 16,20,21,27,28,33-36
WY-26	Seminoe #1	Arch Minerals	Wyoming (Carbon)	T22N, R83W, 1-18,21-24 T22N, R84W, 2,12
WY-27	Seminoe #2	Arch Minerals	Wyoming (Carbon)	T22N, R81W, 4,7-9,16,17 T23N, R81W, 7,8,18,22,26,32 T23N, R82W, 12,13 T22N, R82W, 1,12
WY-28	Sorenson & Elkol	Kemmerer Coal Co.	Wyoming (Lincoln)	T21N, R116W, 4-7,17-21,28-33 T21N, R117W, 24-26 T20N, R117@, 1-4,9-11,14-16,21,22 T22N, R116W, 16,17,20-22,27-29,32,33
WY-29	Twin Creek	Rocky Mountain Energy	Wyoming (Lincoln)	T21N, R116W, 5-9,15-18
WY-30	Welch	Welch Coal Co.	Wyoming	T57N, R83W, 6 T57N, R84W, 1 T58N, R83W, 31
WY-32	Wyodak	Wyodak Resources	Wyoming	T50N, R71W, 9,10,15,21,22,27,28,33 T50N, R72W, 3

DRAFT

"ALLUVIAL VALLEY FLOOR"

Legislative Directions and Interpretations

Definition of Alluvial Valley Floor Consistent with HR 9725:

> "'alluvial valley floors' means the unconsolidated stre[illegible] deposits holding streams where water availability i[illegible] for subirrigation or flood irrigation agricultural a[illegible]
> Source - 701(27) HR 25(94th)

DRAFT

FURTHER DESCRIPTION

"Alluvial valley floors refers to those unconsolidated deposits formed by streams (including their meanders) where the ground water level is so near the surface that it directly supports extensive vegetation or where flood stream flows can be diverted for flood irrigation."
Source - p. 65, Conference Report HR 9725 (95th).

"...alluvial valley floors are the upper, near-horizontal surface of the unconsolidated stream-laid deposits which border perennial, intermittent, or ephemeral streams. The alluvium that makes up the stream-laid deposits is composed of clay, silt, sand, gravel, or similar detrital material that has been, or is being, transported and deposited by streams. Alluvial valleys within this definition are traversed by perennial or intermittent streams or by ephemeral stream channels: are irrigated in most years by diversion of natural flow or ephemeral flood flow on the modern flood plain and adjacent low terraces, or by subirrigation of the flood plain by underflow: and are used for the production of hay and other crops that are an integral part of an agricultural operation."
Source - ibid.

"Excluded...are the colluvial and other superficial deposits that normally occur along the valley margins, are higher than the modern flood plain and low terraces, are not irrigated by diversion of natural flow or by ephemeral flood flow, and are not subirrigated by underflow."
Source - ibid.

"Alluvial valley floors do not include upland areas which are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion, deposits by unconcentrated runoff or slope wash, together with talus, other mass movement accumulation and wind blown deposits."
Source - p. 83, Conference Report HR 25(94th)

"...alluvial valley floors must be (an) integral part of a drainage network that traverses the area...These are part of a through flowing stream (hydrologic) system and are not small areas of isolated internal drainage."
Source - p. 65, Conference Report HR 9725(95th)

"Some characteristics of alluvial valley floors which are essential for agricultural areas include: (1) sufficient runoff to allow for flood water irrigation each year; (2) development of flood plain and low terraces where water can be spread easily without significant mechanical alteration of the surface; and (3) shallow ground water where subirrigation is used and (which) therefore requires a minimum of valley floor dissection so that ground water is not drained."
Source - pp. 82-83, Conference Report HR 25(94th)

"The essential hydrologic functions (to be preserved) are the inherent properties of alluvial valley floors controlling the availability of water under a wide range of natural conditions. Such properties include for instance: interaction between ground and surface water; varying degrees of permeability throughout the deposit; infiltration rates; flow direction and gradients; capability of accumulating, holding and releasing water through drought and seasonal cycles; stability with respect to storm and flood runoff conditions; and maintaining quality of water available to the agricultural uses."
Source - p. 83, ibid.

"The areas involved are those limited sites where natural subirrigation occurs above strippable coal and where sufficient water is available for [illegible] irrigation and diversion from streams."
Source - ibid.

DRAFT

The alluvial valley floor provision was directed to such lands in arid and semi-arid coal mining areas where they (the lands) form the backbone of the agricultural and ranching operation which, in turn, form the basis of the existing regional economic system and where the agricultural and ranching operations could not survive without hay production from the alluvial valley floors. (Derived from p. 64, Conference Report HR 9725)

It was recognized that under site-specific circumstances, it is possible to mine on alluvial valley floors and still be able to assure the maintenance of hydrologic functions of the area (p. 64, ibid and a lesser degree in p. 83, Conference Report HR 25)

APPLICATION OF ALLUVIAL VALLEY FLOOR PROVISION

Under proposed subsection 510(b)(5), the Act is interpreted to prohibit mining in alluvial valley floors if:

510(b)(5)(A) such interrupts, discontinues, or prevents farming on those alluvial valley floors. Excluded are undeveloped range lands which are not significant to farming on alluvial valley floors and lands the regulatory authority finds that even if farming is prevented, they are of such small acreage so as to have negligible impact on the farm's production; or

510(b)(5)(B) would adversely affect the quantity or quality of water (surface and underground) that supplies the alluvial valley floor.

There is also a "grandfather clause" 510(b)(5) for commercially producing operations permitted by a State to operate in an alluvial floor or adjacent to an alluvial valley floor which follows after 510(b)(5)(B), and reads:

> "Provided, that this paragraph (5) shall not affect those surface coal mining operations which in the year preceding the enactment of this Act (1) produced coal in commercial quantities, and (2) were located within or adjacent to alluvial valley floors or had obtained specific permit approval by the State regulatory authority to conduct surface coal mining operations within said alluvial valley floors".

In applying the proposed language of the Bill, we assume the word "impact" is used in the context of a harmful impact on the farm's production but it is not specified what a negligible impact means and thus the discretionary powers of the regulatory authority may be unduly strained without more definitive criteria.

"Undeveloped range land" is somewhat ambiguous, but in the context of alluvial valley floors, we assume that undeveloped range lands are those lands within alluvial valley floors used randomly by grazing animals and which are not cropped for hay or otherwise harvested in a mechanical manner. This wording is in need of more clarity.

Provision (B) is assumed to be directed to protect the quantity and quality of water in those alluvial valley floors with farming activities so that there will be no adverse reduction of agricultural production. We assume that "production" refers principally to grass, grain, alfalfa, or hay as used for fodder. No criteria are given to assist with application of the work "adverse".

In a procedural sense, we are not clear as to how the provision will apply if a surface owner of an alluvial valley floor does not choose to reestablish an agricultural activity on that land after mining; that is, whether mining would be permitted.

DRAFT

CURRENT REGULATIONS - ALLUVIAL VALLEY FLOORS

Under Title 30 Code of Federal Regulations Part 211.40(a)(7) [illegible] mine operator must utilize the best practicable commercially available technology to minimize, control, or prevent disturbances of the hydrologic regime by

"(iv) Protecting the quality, quantity and flow including the depth of both upstream and downstream surface and ground water resources of those valley floors which provide water sources that support significant vegetation or supply significant quantities of water for other purposes, by such measures as, but not limited to, relocating and maintaining the gradient of streams, avoiding mining, installing, reestablishing, or replacing aquifers and aquicludes, and replacing soil..." (30 CFR 211.40(a)(7)(iv).

Definitions:

Valley floors - "channelways, flood plains*, and adjacent low terraces of streams that are flooded during periods of high flow and that are underlain by unconsolidated stream-laid deposits. Excluded are higher terraces and slopes underlain by colluvial and other surficial deposits normally occurring along valley margins." (211.2(qq))

Significant vegetation - "farm crops, including grasses and forbes, that are integral parts of agricultural or ranching operations and the natural vegetation of forests or meadows with significant recreational, watershed, agricultural, or wildlife habitat value." (211.2(11))

Note similarities between these existing regulations and language in Conference Reports accompanying HR 9725 and HR 25.

RECENT USAGES OF ALLUVIAL VALLEY FLOOR PROVISION

As of February, 1977, two bills are before the 95th Congress that address surface mining control and reclamation. HR 2, before the House is similar to proposals made in 1976. That bill says:

"No permit, revision, or renewal application shall be approved unless the application demonstrates...that...(5) the proposed surface coal mining operations, if located west of the one hundredth meridian west longitude, would -

(A) not interrupt, discontinue, or prevent farming on alluvial valley floors that are irrigated or naturally subirrigated, but, excluding undeveloped range lands which are not significant to

*Flood plain refers to relatively smooth land adjacent to a channel constructed by the present flow in its existing regimen and covered by water when the water overflows its banks. It is built of alluvium carried by the water during floods and deposited in the sluggish water beyond the influence of the current. (Modified from American Geological Institute, 1972, p. 267.) Flood plain size increases with a decrease in the probable frequency of a flood. The flood plain used to define an alluvial valley floor in the context of this effort has generally coincided with the annual flood plain which exceeds bank-full stage about every two years.

farming on said alluvial valley floors and those lands that the regulatory authority finds that if the farming that will be interrupted, discontinued, or prevented is of such small acreage as to be of negligible impact on the farm's agricultural production, or

(B) not adversely affect the quantity or quality of water in surface or underground water systems that supply these valley floors in (A) of subsection (b)(5)." (§510(b)(5), HR 2)

The Senate version, S7, under consideration says:

"No permit, revision, or renewal application shall be approved unless application affirmatively demonstrates...that...(5) the proposed surface coal mining operation, if located west of the one hundredth meridian west longitude, would not have a substantial adverse effect on alluvial valley floors underlain by unconsolidated stream laid deposits where farming can be practiced in the form of irrigated, flood irrigated, or naturally subirrigated hay meadows or other crop lands (excluding undeveloped range lands), where such valley floors are significant to the practice of farming or ranching operations, including potential farming or ranching operations if such operations are significant and economically feasible."

DRAFT

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 908/4-77-002	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE SUBIRRIGATED ALLUVIAL VALLEY FLOORS: A RECONNAISSANCE OF THEIR PROPERTIES AND OCCURRENCE ON COAL RESOURCE LANDS IN THE INTERIOR WESTERN UNITED STATES.		5. REPORT DATE March, 1977
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) John E. Hardaway, Dan B. Kimball, Shirley F. Lindsay		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency, Office of Energy Activities, 1860 Lincoln Street, Denver, CO 80295		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS		13. TYPE OF REPORT AND PERIOD COVERED Draft report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

EPA has no plans at present to revise or republish this as a final report. (3/80)

16. ABSTRACT

This draft report discusses the possible impacts which surface coal mining might have upon certain lowland areas in the semi-arid West where shallow ground water and/or soil moisture presently supports the growth of grasses and forbs through the dry summer months. These lowland areas, located along drainage channels and referred to recently as "alluvial valley floors" (National Academy of Sciences, 1974), are most important in semi-arid and arid climates because water is stored in the alluvium, enabling vegetation to continue growth during months of low rainfall. Alluvial valley floors are used for grazing and production of hay, and include points of surface water accumulation and ground water recharge and discharge. Surface mining of coal has the potential, in the western United States, to temporarily, and even permanently, change the ground water flow system. Reconnaissance mapping of subirrigated alluvial floors was conducted to determine how much land might be involved if special legislation evolved to protect areas of agricultural importance, and indirectly, how much coal might be affected if mining of alluvial valley floors was determined to be environmentally unacceptable.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Coal mining Surface mining Environmental impacts Ground water Water table Grazing land Surface water	Site surveys Arid land Semiarid land	Alluvial valley floors Subirrigation Western United States	

18. DISTRIBUTION STATEMENT Distribution unlimited	19. SECURITY CLASS *(This Report)* unclassified	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)* unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

INSTRUCTIONS

1. **REPORT NUMBER**
Insert the EPA report number as it appears on the cover of the publication.

2. **LEAVE BLANK**

3. **RECIPIENTS ACCESSION NUMBER**
Reserved for use by each report recipient.

4. **TITLE AND SUBTITLE**
Title should indicate clearly and briefly the subject coverage of the report, and be displayed prominently. Set subtitle, if used, in smaller type or otherwise subordinate it to main title. When a report is prepared in more than one volume, repeat the primary title, add volume number and include subtitle for the specific title.

5. **REPORT DATE**
Each report shall carry a date indicating at least month and year. Indicate the basis on which it was selected *(e.g., date of issue, date of approval, date of preparation, etc.)*.

6. **PERFORMING ORGANIZATION CODE**
Leave blank.

7. **AUTHOR(S)**
Give name(s) in conventional order *(John R. Doe, J. Robert Doe, etc.)*. List author's affiliation if it differs from the performing organization.

8. **PERFORMING ORGANIZATION REPORT NUMBER**
Insert if performing organization wishes to assign this number.

9. **PERFORMING ORGANIZATION NAME AND ADDRESS**
Give name, street, city, state, and ZIP code. List no more than two levels of an organizational hirearchy.

10. **PROGRAM ELEMENT NUMBER**
Use the program element number under which the report was prepared. Subordinate numbers may be included in parentheses.

11. **CONTRACT/GRANT NUMBER**
Insert contract or grant number under which report was prepared.

12. **SPONSORING AGENCY NAME AND ADDRESS**
Include ZIP code.

13. **TYPE OF REPORT AND PERIOD COVERED**
Indicate interim final, etc., and if applicable, dates covered.

14. **SPONSORING AGENCY CODE**
Insert appropriate code.

15. **SUPPLEMENTARY NOTES**
Enter information not included elsewhere but useful, such as: Prepared in cooperation with, Translation of, Presented at conference of, To be published in, Supersedes, Supplements, etc.

16. **ABSTRACT**
Include a brief *(200 words or less)* factual summary of the most significant information contained in the report. If the report contains a significant bibliography or literature survey, mention it here.

17. **KEY WORDS AND DOCUMENT ANALYSIS**
(a) DESCRIPTORS - Select from the Thesaurus of Engineering and Scientific Terms the proper authorized terms that identify the major concept of the research and are sufficiently specific and precise to be used as index entries for cataloging.

(b) IDENTIFIERS AND OPEN-ENDED TERMS - Use identifiers for project names, code names, equipment designators, etc. Use open-ended terms written in descriptor form for those subjects for which no descriptor exists.

(c) COSATI FIELD GROUP - Field and group assignments are to be taken from the 1965 COSATI Subject Category List. Since the majority of documents are multidisciplinary in nature, the Primary Field/Group assignment(s) will be specific discipline, area of human endeavor, or type of physical object. The application(s) will be cross-referenced with secondary Field/Group assignments that will follow the primary posting(s).

18. **DISTRIBUTION STATEMENT**
Denote releasability to the public or limitation for reasons other than security for example "Release Unlimited." Cite any availability to the public, with address and price.

19. & 20. **SECURITY CLASSIFICATION**
DO NOT submit classified reports to the National Technical Information service.

21. **NUMBER OF PAGES**
Insert the total number of pages, including this one and unnumbered pages, but exclude distribution list, if any.

22. **PRICE**
Insert the price set by the National Technical Information Service or the Government Printing Office, if known.